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THE EFFECT OF CIVILIZATION UPON THE LENGTH OF LIFE OF THE AMERICAN INDIAN

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THE ways in which the illiterate peoples of the earth adjust their modes of life to the civilization of the white man is now the objective of many inquiries. The rising tide of white culture has all but engulfed them. As residents of the United States or Canada we are conscious of our surviving Indian tribes as little islands in this flood. We have been told that one by one these little clusters of aboriginal humanity are being drowned out, but this is an exaggeration, since few tribes have disappeared. The Indian's resistance has been by no means low, nor has he been entirely inept in adjusting himself to our rapidly changing economics.

Before the great depression set in we gave the Indians a neck-breaking race to keep in sight of us, but now they enjoy a breathing spell. For a long time we have pointed an accusing finger at them because they received food, clothing, etc., from the government, whereas now so large a part of our own population is dependent upon similar aid that it is the Indian's turn to call us to account for our extravagance and lack of initiative. However, the intent of this communication is to consider certain aspects of the Indian's struggle to keep in sight of white economic and social changes. It is this attempt of the Indian to work out his destiny that calls for investigation by students of social processes.

Most students of Indian acculturation have approached the subject from a psychological angle. They think of the Indian idling in his cabin, depressed over his degradation and poverty, whereas his standard of living is now far higher than his aboriginal ancestors enjoyed. Few Indians living in the United States to-day were born before reservations were established, so much of what Indians in general know of the old economic life is tradition rather than reality. Further, they are rapidly becoming bi-lingual and literate. True, they cherish many old forms and beliefs, but so do their white neighbors. The Indians now ride in automobiles, go to picture shows, use radios, etc. Nevertheless it is apparent that they are not saturated with our national culture but straggling in the rear. It remains to be seen whether if the reservation Indian is really depressed such unhappiness is due to his consciousness of maladjustment to white culture. Whatever may be the truth here, it is the social phenomenon so presented that has intrigued many students and which is to-day a subject of exploration by the U. S. Indian Service and social anthropologists.

Yet in all such studies the approach

has been almost wholly psychological and social, so it occurred to us that a biological approach might contribute something additional to an understanding of the situation. The average reservation group of Indians is a community of about a thousand persons, and if we fix our attention upon this mass of living humanity, whose individuals are constantly changing through age, birth and death, we begin to be curious as to how these biological groups stand up under the impact of civilization. A guess might be that when first put upon reservations the strain of adjustment was greatest. Death and disease might then take the greatest toll, but as the Indian gained in his efforts to adjust his mode of life to new conditions, the losses would decrease. In other words, a history of death, birth, disease, etc., would be the first consideration.

For such a study one needs good statistics. Preliminary exploration convinced us that the Canadian Indian Department possessed the most accurate data, but that those for United States Indians, though less satisfactory, were usable. Accordingly we chose the Indians of the Northern Plains as a test group—the Western Cree, Assiniboin, Gros Ventre (Atsina), Blackfoot, Blood, Piegan and Sarsi. These tribes are now living in Alberta, Saskatchewan and Montana. They reside on seventy reservations, administered under nineteen agencies. Seventy-four bands or social divisions are recognized, each of which occupies definite reserve lands and the population data for which are recorded separately. For this study we have used the totals for the respective tribal groups.

The data were tabulated by Mrs. R. A. Sanderson, honorary life member, American Museum of Natural History.

POPULATION HISTORY

Our first concern is with the gross population history of these tribes. Table I shows that these Indians began reservation life with a population somewhat greater than they now have, but that the low point was reached about 1904. We think this means that for a time the strain of reservation life was great, but that eventually a turning point was reached.

Such a gain in population might be brought about by an increase in the birth rate, a decline in the death rate, or both. So we next sought for data on births and deaths. The birth rates were compiled for these separate reservations, showing approximately 42 per thousand population for the whole group of tribes between 1884 and 1934 (Table I). The rate was tabulated annually and the rate of 42 is an average per five-year intervals. The interesting point is that the rate is constant and probably is the same as the birth rate of these Indians in prereservation days.[1] In other words, whatever the impact of white culture upon the physiology of these Indians, the reproductive function resisted effectively. Then, naturally, if population rose and fell with a constant birth rate, we must look to the death rate for an explanation. Incidentally we remark that 42 is a high birth rate, perhaps near the physiological maximum.

TABLE I

POPULATION CHANGES IN THE RESERVATION PERIOD

	1884	1904	1934
Population ...	22,281	14,645	19,536
Birth rate	42	42	42
Death rate ...	70*	52	33

* Estimated.

Indian death rates were found highly variable. They vary also as between reservations. The highest rate for any year was 100; the lowest, 27. Our tables suggest that the lowest level of population was reached about 1904, but the total death rates after reaching a maximum peak about 1892 declined gradually to the present.

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[1] Ferguson reports a similar constant rate for certain Cree reservations. Wissler, *Proc. Nat. Acad. Sci.*, Vol. 22, No. 3, 1936.

Thus we find the death rate seemingly sensitive to the impact of reservation life. Yet the trend has been steadily downward from early reservation days, and though still much higher than the white rates for corresponding regions, we have good ground for predicting that eventually it will drop to the white level. Should the birth rate remain high, Indians will then become conspicuous in our population, because each downward step in the death rate would further accentuate population growth.

When these Indians were first placed upon reservations, disease took a heavy toll. The inclination has been to explain this as due to a depressed and discouraged state of mind. This was a factor, but when people are thrown together in a new way, as in concentration camps, there is a rapid rise in disease. Placing these Indians upon reservations was analogous to a system of concentration camps and the government reports show that measles, colds, diphtheria, pneumonia, etc., soon appeared, just as in a military camp for recruits. Hence, there seems no reason for assuming mental and emotional distractions as the chief causes for the high death rates. We note, then, that a few years after these Indians had been placed on reservations, the death rates turned downwards, this trend persisting to the present.

However, officials in charge of reservations regard their job as not complete until the death rates for the Indians under their care approximate those among the surrounding white population. They have implicit faith that when these Indians come to live like white people their death rates will approximate those of their white neighbors. This expectation may not be fully realized, but our studies suggest that it will be approximated.

The reservation records show that changes in housing, clothing, food, etc., were progressive throughout the period 1880 to 1935. The standards were set by the changing white culture, hence the foregoing means that these Indians were progressively adjusting themselves to white modes of life. The significant observation is that since the initial shock of reservation life, the continued fall of the death rate has been coincident with progressive changes in the mode of life.

MINORS AND ADULTS

Students of population know that the hazards of life often vary with the age of the individual, and it has been observed that the death rates for age classes vary. The early records for the Indians studied recorded individuals by sex and classified them as minors and adults. This enables us to observe what happened to these classes in the population as the mode of life changed. If reservation life bore hardest upon minors, their numbers should decrease relatively.

TABLE II

MINORS AND ADULTS AMONG THE CREE INDIANS PER THOUSAND POPULATION

	1894	1914	1934
Adults .	564	475	467
Minors	436	525	533

First we note the relative numbers of minors and adults among the Cree Indians (Table II). In 1894 there were more adults than minors, but the relation is reversed in 1934. Our data for other tribes indicate the tendency to be for minors to increase from year to year after the beginning of reservation life. Such a relative increase suggests that the death rate for minors is falling. The death rate for adults is falling, too, but obviously at a much slower pace. We see, then, that reservation life is becoming relatively more and more favorable to minors.

The reservation records for later years group populations under five arbitrary age periods, as in Table III. Tabulating these data, we find that age groups 0–5, 6–15 and 65 + are increasing; 16–20 and

TABLE III

TREND IN AGE GROUPS PER THOUSAND POPULATION FOR THREE TRIBES—MALES

Ages	1900	1934
0– 5	78	98
6–15	99	106
16–20	55	47
21–64	240	231
65+	19	24

21–64 decline. We observed this decline to be regular and the same relatively for each tribe. Thus even small differences became significant.

Recalling that minors as a whole increased relatively we see that what actually happened was that the children of ages 0–15 increased relatively, whereas persons 16–64 years decreased. This is to say that reservation life was favorable to the survival of children 0–15 years of age and increasingly so; also favorable to those of 65+. On the other hand, the same mode of life bore hard upon individuals 16 years and over. We should, then, like to know whether more Indians died during the period 16–20 than later. Had we data for the ages of death the solution would be easy.

CHANGES IN SEX RATIOS

So much for age classes; we now turn to sex grouping. The first explorers in the northern plains noted the unusual excess of women; no count was necessary to reveal the male minority. In 1809 Alexander Henry, the head of a fur-trading company, made a census of the tribes we are considering with the following result: 4,823 men, 13,632 women, 45,906 minors. We know nothing as to how this count was made, but the potential consumption and production of the various tribes was of first importance to the trade. Any one reading Henry's journal will be impressed by his painstaking accuracy in all the affairs of life. Reducing Henry's figures to relative terms there were approximately 74 men, 212 women and 714 minors in a thousand population. As a test, we found that among a division of the Cree Indians in 1904 there were 177 men, 212 women and 611 minors per thousand population. This is the highest rato for minors observed by us, but other tribal groups approach it, so there is nothing improbable in Henry's census of 1809. In 1904 men were more than twice as numerous as in 1809. Should our 1904 population have had a similar small number of males, the number of minors would have been as great as in 1809. For example, if in 1904 the men were reduced to 74 per thousand, assuming that the others were killed in hunting and war and that there were no such losses among women, then the case would stand as in 1809. So the differences between 1809 and 1904 are not distressing. Where the taking of more than one wife is good form, the number of wives per man is entirely dependent upon the number of women.

In the previous section we noted that on reservations the trend has been toward an equality and eventually an excess of minors over adults. Such might be expected with a constant birth rate, if the relative number of males increased. So we turn directly to the relative number of men and women. There is some evidence that when these Indians were placed upon reservations women were still in the majority.

TABLE IV

TOTAL RATIO FOR TRIBES STUDIED

	1894	1934
Men ...	246	248
Women	326	232

Since reservations were established about 1880, it is assumed that then women were more numerous than in 1894. Even if the causes resulting in more women than men ceased to operate in 1880 the survival of women would easily account for a declining excess, or the observed trend. Taking 1809 as the starting point with 76 men per thousand the suggestion is that by 1894 the relative number of men had risen to approximately one fourth of the population, but there was still an excess of women; however, in 1934 the women were slightly in the minority. So as a general proposition we can say that in aboriginal times men were in the minority, but that reservation life inaugurated a trend toward equality and eventually to an excess of males.

Naturally the question arises as to the causes for such changes. There are at least two possibilities; more females may have been born or the death rate for males may have been abnormally high. We have no data on the sex birth-ratio for the tribes studied, but among a Dakota Indian community in the United States the ratio is about 106 males to 100 females. This is similar to United States white and other national ratios. We can, however, shift our approach to the sex ratios for age classes. In respect to minors we note that for the Cree Indians the sex ratios of minors are comparable, as:

TABLE V
SEX RATIOS OF MINORS

	1904	1919	1929
Male	249	268	253
Female . . .	249	266	258

On the other hand, female adults exceeded males by about 15, 14 and 10 per cent., respectively. This would seem to suggest that the relative loss of males was not conspicuous before twenty years of age.

However, for two Cree reserves at Carlton, Canada, we have data for an age grouping. These reserves are still conspicuous for their continued excess of women. The peculiarity, however, is that males begin to fall behind after the age of sixteen years. Further, we had data for calculating the death rates in this group by sex, minors and adults. The average rates per thousand for the period 1899–1932 were:

	34
	22
	15
Women	16

Inspection of the data indicates that the heavy losses among males come just after sixteen and return to normal at about twenty-five. Thus some hazard besets males between the ages of 16 and 25.

The most direct approach to an understanding of this loss of males would be a study upon the ground, but that is impractical at present. Anyway we believe the answer can be had from the data at hand.

WOOD CREE

If our assumption that these observed trends are due to modes of life is justifiable, then wide culture differences between Indian reservations should also register in population distinctions. The Indians represented in Table VI are known as Wood Cree and Plains Cree. A century or two ago all these Cree were Wood Cree, living chiefly on the edges of the plains but gradually drifting out into the open plains. When located on reservations, the lands assigned the Cree were on the edges of the plains, near the transition forest zone. Those now called Wood Cree had not wholly taken to plains life when the reservation period opened. The true Plains Cree could no longer kill buffalo, so they were given rations. On the other hand, the Wood Cree could still support themselves in part by hunting and trapping in the adjoining forests and have so continued to this day. So, in brief, there is a wide difference between the modes of economic life followed by the two divisions of Cree. Table VI shows the population differences between them. In number of minors Wood Cree lead; they have a marked excess of women over men; their birth rate is the same as other Indians, but the total death rate is lower. However, the exceptional Carlton death rate for minor males, and the lower number of males for the age group 16–20, occur in a division classed as Wood Cree.

In an earlier paragraph we noted that the age group 16–20 was diminishing relatively among all Plains Indian groups; there was practically no difference between males and females. Yet for the Carlton group the number of males in the 16–20 group was decidedly lower than females. This is consistent with the high death rate for all Carlton male minors. We think it safe to conclude that the sudden loss of males occurs at this time.

As stated, these Wood Cree males engage in trapping and hunting, especially the adolescents and young adults. The hazards in such a life are great. The officials in charge of these reserves report that many male lives are lost from undue exposure and accidents incident to trapping excursions We see, then, an occupational hazard and one which could have operated in aboriginal times. If we add the hazards of the war trail in pre-reservation days, the scarcity of men in the census of 1809 is not surprising However, all such effects are directly traceable to social or cultural factors, and so it is the mode of life which contributes to such changes in population among the Indian tribes we have studied

TABLE VI

WOOD AND PLAINS CREE

	Wood Cree				Plains Cree			
	Minors		Adults		Minors		Adults	
	M	F	M	F	M	F	M	F
1909	254	280	211	255	241	248	241	270
1919	273	300	198	229	241	248	246	265
1934	238	283	222	257	263	267	233	237

AGE-AT-DEATH PROFILES

Population statistics for civilized countries present tables recording age-at-death, and the plotting of such frequencies gives interesting profiles. Clements[2] first called attention to some wide differences between such profiles for Indians, Negroes and whites.

These differences result from variations in the death rates for the respective age groups. Though for the Indian reservations studied by us there were no records of deaths, yet we noticed that when living Indians were classified according to age, the frequencies were different from either white or Negro. For Indians we found that there were definite trends in age grouping. On the whole they seemed to be approaching the white people, though slowly. So we came to suspect that as these Indians approach equality with whites in most of the details of living, their age-at-death profiles will approximate those of the white population living around their reservations. If so, the form of the profile will vary with the mode of life and doubts arise as to the existence of race differences in such profiles. It seems fair to assume, then, that age-at-death profiles are not constant but reflect changes in mode of life.

The quantity of Indian data available is hardly sufficient for a fair test of this assumption, but if the principle holds, it should follow that wide differences among white and Negro communities should register in their age-at-death profiles. So we turned to the United States census.

We chose Ohio and Louisiana as random samples of white population. Limiting our experiment to what the census classes as rural populations, we have profiles as in Fig. 1. While these profiles have similarities, there are real differences. For most of the states similar age-at-death tables for whites are given in the census, between many of which there are conspicuous differences. We think it is a reasonable assumption that these differences are due to differences in the social factors making up the complex we call the mode of life.

Next we sampled the census tabulation of Negro deaths. This revealed regional differences, illustrated in Fig. 1. Again using Ohio and Louisiana as samples we observed that the Negro profiles differ from each other even more than did the white profiles. Again Negro and white

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[2] F. Clements, *Human Biology*, 3: 397–419, 1931

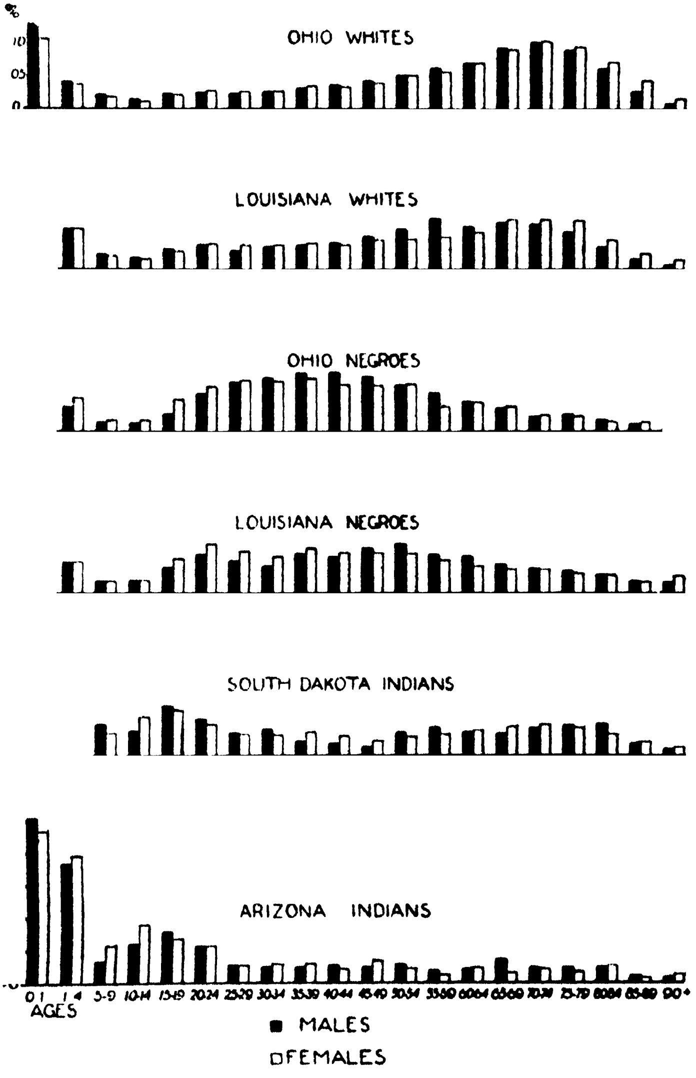

FIG. 1. AGE-AT-DEATH FREQUENCIES FOR WHITE, NEGRO AND INDIAN GROUPS IN DIFFERING ENVIRONMENTS

THE DATA ARE FROM THE UNITED STATES BUREAU OF THE CENSUS, MORTALITY STATISTICS, 1928; TWENTY-NINTH ANNUAL REPORT, WASHINGTON, 1930. COMPILED BY MRS. R D. SANDERSON, HONORARY LIFE MEMBER, AMERICAN MUSEUM OF NATURAL HISTORY.

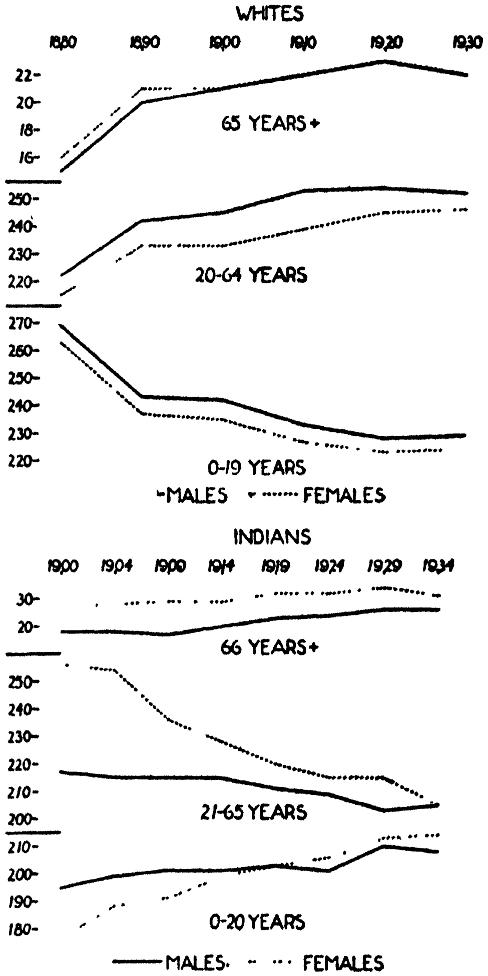

FIG. 2. AGE GROUPING PER THOUSAND POPULATION FOR INDIANS AND WHITES

NOTE THAT THE INDIAN AGE GROUP 0–20 GAINS, WHEREAS AMONG WHITES THE GROUP 0–19 DECLINES. ADULTS DECLINE AMONG INDIANS BUT GAIN AMONG WHITES THE ELDERLY GROUPS GAIN IN BOTH. SEX DIFFERENCES ARE CONSPICUOUS; MALES EXCEED AMONG WHITES, FEMALES AMONG INDIANS. THE INDIAN DATA ARE FOR ALBERTA AND SASKATCHEWAN, CANADA, AND THE WHITE DATA FROM THE UNITED STATES CENSUS.

differ in each case. We tabulated Negro data for a number of states; Pennsylvania, Illinois, Wisconsin, California and the State of Washington presented the Ohio form of profile, Mississippi and Georgia a profile like that for Louisiana. As a further test we tried Negroes in Oklahoma, Kentucky and Maryland, finding their profiles intermediate to Louisiana and Ohio.

The result of this experiment was satisfactory. The differences are real enough. We assumed that the total complex called "mode of life," in Ohio, for example, is not the same for white and Negro, nor is it quite the same as for whites and Negroes in Louisiana. Further, we doubt if any one would expect the mode of life followed by Negroes in Ohio to be precisely like that of Negroes in Louisiana.

It was not our intention to analyze these local white and Negro populations with a view to isolating the causes of the observed differences. Our problem lies with the Indian. However, if it is proposed that migration, inaccuracy in age, early marriage, birth control, education, etc., account for the differences, our initial assumption stands, since these are all social factors embraced in the mode of life. Again, the reader may feel that we have not given disease its due. We do not claim that all deaths are due to mode of life, that would be absurd, but it seems probable that the number of young people dying between 15 and 25 years, for example, will vary greatly with the mode of life. The contrasts in infant mortality between civilized and primitive peoples have long been recognized; the very high rate among primitive peoples is attributed to their mode of life. Disease may well be something apart from mode of life, but the number of persons stricken and the number that die seem to vary with the social behavior of the group.

The data for American Indians make it clear that the age-at-death curve has changed as the mode of life changed. The birth rates for the tribes we have studied remained stubbornly constant from the day they were forced to give up their free life and settle down upon reservations. The life upon reservations called for a rapid change in mode of life; we find coincident changes in the death rates. Until recent years there were no reliable data for age-at-death ratios, but there were indirect data showing that the age-at-death ratios must have changed progressively.

From the census we compiled Indian deaths for Arizona and South Dakota. These Indians do not live under the same conditions, and their original modes of life were widely divergent. Differences appear in their profiles, Fig. 1. Further, we found the profiles for the Indians of North Dakota, Washington, California and Ontario closely similar to South Dakota. On the other hand, New Mexico, Wisconsin and Alberta resembled the profile for Arizona.

We have, perhaps, carried these illustrations far enough to support the assumption that the age-at-death sex profiles are sensitive to modes of life, including whatever other factors influence the survival of the individual. However, it can be demonstrated that all Negro communities in the United States have some social factors in common, so have white communities and Indian tribes in the United States and Canada, which is consistent with some apparent general differences between white, Negro and Indian profiles. On the other hand, the wide differences within these race groups is consistent with the conclusion that these differences are not constant and chiefly dependent upon the mode of life.

RÉSUMÉ

We have briefly explored such vital statistics as were available respecting certain Indians living upon reservations and in process of acquiring the modes of life pertaining to the surrounding white population. We noted that the population profiles for these Indians were determined by varying death rates for sex and age groups. The marked excess of women we found due to exceptional occupational hazards for men, to which in pre-reservation days were added the hazards of predatory warfare. On reservations where occupations are now similar to those of rural whites we find Indian women and men now approximately equal. Age grouping revealed progressive changes among both males and females. The death rates for such groups showed changes coincident with changes in modes of life. In other words, the population profile was found sensitive to social changes in the group. A comparison of such profiles would then indicate roughly similarities in modes of life. We conceived the mode of life as a complex of practices favorable, neutral and unfavorable to the survival of the individual. The population profile would be the resultant of all factors operating, social and otherwise. The evidence so far suggests that the crude death rates for two tribes of Indians might be equal, but numerous variations in their modes of life result in distinct population profiles.

The social sciences have now become interested in observing how such formerly primitive groups as Indians adjust their modes of life to white culture. The process of becoming a white man is often spoken of as acculturation. The Bureau of Indian Affairs in Washington is now in need of a method by which reservations can be classified according to the degree of acculturation attained. The suggestion made here is that an improved system for recording vital statistics will furnish one index to acculturation.

THE INFLUENCE OF THE SUN ON HUMAN AFFAIRS

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THE study of the effects of the sun on affairs on the earth opens many interesting possibilities. Aside from the more obvious changes that take place as the result of seasonal variations in the amount of sunshine, there are changes going on in the sun itself which may have far-reaching counterparts in terrestrial affairs

Probably every one is aware that there is a more or less definite cycle of about 11¼ years through which the sun passes from one disturbed condition to another. Whatever the effect of these physical alterations in the sun's behavior may be, and whatever may be their ultimate cause, they are marked by the observation of hurricanes in the solar atmosphere; hurricanes that would make the most violent of our tropical disturbances appear insignificant in comparison. The storms consist of vortical whirls raging on either side of the sun's equator. Clouds of hydrogen, calcium and the vapors of other elements spiral about in a clockwise or counter-clockwise direction, attended by violent currents in the solar atmosphere. In the heart of these stormy areas the temperature is sufficiently lowered to produce an appreciable darkening in the brilliancy of the solar surface, as seen through a telescope. These darkened areas which appear by contrast as black spots have been known as sun-spots as far back as the invention of the telescope in the early seventeenth century. Even prior to the telescope era disturbances of this character had occurred of such huge dimensions as to be recorded in certain instances by the naked eye, probably during the sunrise or sunset hours when the earth's atmosphere screens the harmful rays and allows one to see the reddened disk of the sun with the unprotected eye.

Systematic observations of sun-spots have been made for more than 300 years so that the definite rise from minimum to maximum in the numbers of these spots has been well established for at least some 20 cycles. The last period of maximum disturbances occurred during the years 1928–29, July 1, 1928, being the approximate middle date marking the top of the last maximum of the sun-spot curve. The autumn of 1929 showed a large drop in the number of sun-spots which, incidentally, can be remembered by the season of a rapid fall in certain terrestrial markets. Sun-spots continued to decrease until they reached a minimum in September, 1933. Since that time, they have been definitely increasing and during the last year have gained rapidly in numbers and in size.

The so-called "sun-spot number" is a characteristic figure derived from observation and takes into consideration not only the actual number of spots but the number of the groups of spots as well. To reconcile the results of telescopes of various apertures a coefficient is introduced into the formula for deriving the sun-spot number of a given date. One characteristic in the development of the sun-spot cycle concerns the position of these spots on the sun's surface. The disturbances invariably break out at relatively high latitudes on the sun. With the progress of the cycle the spots increase in number in both hemispheres and at increasingly lower latitudes until the maximum is reached in the neighborhood of solar latitude 20° either side of the equator. Thereafter the spots decrease until the few survivors vanish within 4° or 5° of the solar equator. Almost never are spots seen higher than the latitude 40° or within less than 5° of the equator.

Watching the spots for a few days in succession will reveal to one that they drift across the solar disk, showing that the sun rotates on an axis. From the motion of the spots it is found that the sun's axis is inclined to the plane of the earth's orbit some 7°. In June and December the earth is in the plane of the sun's equator. Early in September the north end of the sun's axis is tipped 7° towards the earth and, therefore, spots in the northern hemisphere of the sun having latitudes of this amount may pass directly in a line with the earth Similar circumstances occur for the other hemisphere of the sun six months later. This has an important bearing on the question of the effects of sun-spots on the earth, since there is some evidence for believing electrically charged particles may be propelled from sun-spots toward the earth when they are suitably located. A point on the solar equator is carried completely around the sun with respect to the earth in just 27.3 days. At higher latitudes the sun rotates more slowly, and near the poles some 35 days are required for one rotation. This, of course, shows that the solar surface consists of a luminous gaseous atmosphere. The difference in rotation at different latitudes causes, therefore, a shearing or dragging effect in the different zones which is most conducive to causing cyclonic whirling in the region of sun-spot zones.

All sorts of fantastic calamities on the earth have been blamed on sun-spots. Droughts, floods, hurricanes, the productivity of fur-bearing animals and the weather, even economic depressions have all come in for their share of correlation with solar phenomena. Whether or not there is any scientific basis for presuming such intimate relationship between the sun and the earth, the most conservative scientists are agreed that the characteristics of the mysterious earth's magnetic field change step by step with the sun-spot cycle. More than 200 years of observations of the earth's magnetic activity, as is evidenced by the wandering of a compass needle, substantiates beyond doubt that magnetic disturbances on the earth accompany these solar disturbances that we call sun-spots. Not, however, until early in the present century did we have any clue either from the solar or from the terrestrial end as to why such a connection should be evidenced

It was in 1908 that Dr. George E. Hale, founder and first director of the Mount Wilson Observatory, announced the true cyclonic character of sun-spot disturbances. As soon as it was evident that hot solar gases were whirling at terrific velocities about the sun-spot centers, it could be seen that if such gases were ionized or carried electrically charged particles, then huge currents of electricity must be flowing around the vortex creating a magnetic field within the sun-spot itself. Confirmation of this hypothesis came about through the brilliant demonstration of the changes in the frequency of the light waves emanating from the vicinity of sun-spots. It was in 1896 that Zeemann showed in the laboratory the effect of the magnetic field upon the behavior of light. Hale found the identical effect in the light from sun-spots, thereby showing unmistakably that the sun-spots in themselves were centers of powerful magnetic fields many times stronger than the magnetic field of the earth. Thus, from the solar end came the first clue as to the cause of magnetic changes in the earth accompanying the occurrence of great sun-spot outbreaks.

The second clue, this time one from the earth end of the chain, came about through the advent of the radio. In the early days of wireless transmission it was thought that these electromagnetic waves traveled in straight lines and therefore could not be picked up at great distances on account of the curvature of the earth. Only by building higher and higher antenna towers was it thought possible to increase the range of wireless communication by the early experimenters. However, some observers thousands of miles from the original wireless stations were eavesdropping and heard signals from the distant towers that were well beyond the limit forbidden by theory. Since observation is the last court of appeal in science it is obvious that the theory of wireless transmission had to be revised.

It was then that Professor A. E. Kennelly of Harvard ventured the hypothesis that the upper layers of the earth's atmosphere were electrified or ionized by the sun's radiation falling on it and formed a conducting, and hence an excellent reflecting shell, for turning back toward the earth the wireless waves which had ascended skyward. The English scientist, Heaviside, was seized with the same idea at about the same time and made a similar announcement a short time after that of Dr. Kennelly. In honor to the imagination of these gentlemen, radio technicians to-day refer to the ionized strata in the earth's atmosphere as the Kennelly-Heaviside Layer.

With the advent of radio broadcasting stations for the public benefit, a new tool was now in the hands of the scientist for investigating new changes in the electrical state of the upper atmosphere. Austin, Pickard, Appleton and others, including the author, became interested in systematic measurements of intensity of the carrier waves sent out from broadcasting stations to see if by any chance long periods of fading or increasing intensity might not show some correlation with solar phenomena. By the time of the sun-spot maximum of the years 1928–29, sufficiently quantitative results were in hand to prove beyond much doubt that the ionization or electrical condition of the earth's upper atmosphere responded promptly to the outbreak or decrease of sun-spots. Combining the knowledge gained from the magnetic character of the sun-spots themselves and the knowledge of the electrical condition of the earth's atmosphere obtained through radio measurements, it becomes possible to see how magnetic changes in the earth follow solar disturbances. The magnetic field of the earth is due partly to a kind of sub-permanent magnetism, apparently hidden within the earth itself, which accounts for the north magnetic pole some 1,400 miles from the true geographical pole. It is also partly due to the magnetic effect of the electrified shell of the earth's atmosphere in rotation about the true geographical pole as the earth turns on its axis. The combination of these effects may well account for the diurnal variation in the direction of the compass observed at all magnetic observatories. Anything then which disturbs or changes the degree of ionization or the number of charged particles in this electrified shell of the earth's atmosphere will alter the amount of magnetism induced in the earth through the rotation of this shell.

If we may suppose that electrons or other charged particles are ejected from the sun's surface, then in the vicinity of sun-spots they would tend to stream away radially through the center of the spot guided by the electromagnetic field created by the spot itself. When sunspots are near the sun-earth line, we should expect the most marked effect on the magnetic changes on the earth. From careful study of great magnetic disturbances between the years 1875 and 1903, Maunder was able to show that the sudden commencement of such disturbances in every case corresponded to the passing of a large spot near the central meridian of the sun. The average time

elapsing between the meridian passage of a spot and the commencement of the corresponding magnetic disturbance on the earth has been found to be about 30 hours. During these magnetic disturbances on the earth we witness unusually brilliant displays of aurorae. A Norwegian scientist, Dr. Störmer, has shown that the gorgeous displays of the northern lights could be well accounted for on the supposition that electrified particles are entering the earth's atmosphere at such times in unusual quantities. Deflected by the earth's magnetic field these streams of particles tend to converge in the neighborhood of the north pole, thus increasing the ionization of the earth's upper atmosphere in that neighborhood, causing incandescence or illumination similar to that caused by the cathode rays streaming through a vacuum tube similar to that employed for x-ray examinations. The greater frequency of auroral displays at sun-spot maxima appears to be an argument for the emission of charged particles from the sun directed earthwards by the magnetic fields of sun-spots.

Some scientists attribute the increased ionization of the earth's upper atmosphere to an increase in the ultra-violet light of the sun, which is presumed to take place with a general increase in solar activity. Observations by the author, however, would seem to show that changes in radio reception follow more closely the outbreak of spots in the central region of the sun than a change in the intensity of the ultra-violet light from the sun as has been measured during the last decade. Furthermore, if the curve showing changes in the intensity of radio reception plotted against the occurrence of sun-spots in the central zone of the sun, and therefore near the sun-earth line, be compared with a similar plot based on the number of sun-spots seen on the whole disk of the sun for the ne years, it becomes evident that the in radio intensity follow much more closely the curve of sun-spots in the central zone. This, then, seems to argue for a true sun-spot effect in explaining the disturbances in the ionosphere that affect radio reception.

From time to time various reports appear to indicate that there is a close correspondence with the character of radio reception and changes in the weather. The presence of a "high" or a "low" of barometric pressure appears to have considerable influence on both the intensity and the direction of the radio wave propagated from a given broadcast station. If, as appears to be the case, we have definitely established a relation between the behavior of radio reception and the occurrence of sun-spots, and if it should become substantiated that there is direct relation between changes in the weather and radio reception, we shall perhaps find in the radio a new link to aid in answering the question often asked: "Is there any relation between sun-spots and the weather?"

Quite apart, however, from any radio observations, H. Helm Clayton has found considerable evidence for changes in barometric pressure over the earth accompanying changes in solar activity. In years of sun-spot maxima he has shown[1] that the atmospheric pressure is lower in the equatorial region covering a belt of about 30° north to 30° south latitude. At this same time of maximum solar activity the pressure is shown to be higher in both hemispheres from about latitude 35° to 65°. There is also some evidence that the tracks of the highest and lowest or the familiar anti-cyclones and cyclones which produce our short period weather changes migrates through a limited range during the 11-year solar cycle. Dr. Abbot at the Smithsonian Institution has been measuring the intensity of the solar radiation for several decades not only at Washington and California but at remote stations in Chile and Africa. With apparatus of great precision he has found that there is in general a falling off in the amount of heat the earth receives from the sun during sun-spot minima as recorded at all stations. A corresponding rise in the amount of heat received from the sun by the earth accompanies the rise to sun-spot maximum. The total range in the value of this solar radiation, or the so-called "solar constant," is of the order of about 3 or 4 per cent.

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[1] "The Atmosphere and the Sun," by H. Helm Clayton. Smithsonian Miscellaneous Collections, Vol. 82, No. 7, June 9, 1930.

Perhaps one of the most remarkable and most romantic stories in science relative to sun-spots and seasons of dry and wet weather is to be found in the work of Professor Douglass at the University of Arizona. Dr. Douglass has given a life-time to the study of tree rings. Many of us strolling through the woods have amused ourselves in counting the rings left in the stumps after a recent clearing, thereby determining the age of the tree. Perhaps fewer of us have been aware of the inequalities of the spacing of those same rings Where the annual rings are widely separated we have the record of years unusually favorable to growth. Where the rings are narrow, we have similar records of years less favorable to growth. From the study of many thousands of trees, Dr. Douglass has been able to show very definitely that years of drought and relatively wet weather in the southwestern part of the United States show a close correspondence with the sun-spot cycle, The Arizona redwoods and the California sequoias appear to have been recording years of maxima and years of minima in the movements of sun-spots even long before the invention of the telescope. To analyze the complex data which he collected, Dr. Douglass devised a special apparatus called a cyclograph, w[illegible] proved a great aid in discovering these cycles hidden in tree-ring growth. While the 11-year sun-spot cycle could be traced very definitely through the century, Douglass was much perplexed by the apparent lack of any significant cycles during the latter part of the seventeenth and early part of the eighteenth centuries. In fact, his theory of sun-spots affecting tree growth broke down so exasperatingly during this period that he nearly abandoned the idea of connecting sun-spots with weather cycles. It was in 1922 that Professor Maunder, however, called Professor Douglass's attention to the fact that old astronomical records had turned up, showing a great dearth of sun-spots from 1645 to 1715. This was cheery news, for it is obvious that the trees behaved just as they should have behaved in giving no definite indication of a sun-spot cycle during this interval.

While Professor Douglass interprets the spacing of his tree rings in terms of periods of drought and wet weather, it seems not unreasonable to suppose that there may be other factors besides precipitation which enter into the favorable growth of trees. Perhaps the amount of sunshine, variations in its quality and the proportional amount of heat and ultra-violet light in the sun's beams are other factors favoring growth. The tree, therefore, may be looked upon as a biological specimen which has integrated all the favorable factors to growth which pass through cycles corresponding to cycles in solar activity.

If trees, then, may be regarded as scientific recorders of changes in the sun, one may well ask, "Are there other biological specimens which may in one way or another be expected to respond to changes in the solar cycle?" We have now to mention again the data that have been collected from the records of pelts of fur-bearing animals. That the number of rabbit pelts reported appears to vary inversely with the sun-spot curve may or may not show a causal relation [illegible] ae productivity of the rabbit and solar activity. One might, of course, have to suppose that the energy with which the trappers pursued their vocation had its effect upon the rabbit curve. Nevertheless, joking aside, the periodicities long observed in fur-bearing animals offer food for thought. One of the most puzzling difficulties in dealing with these even conspicuous cycles is the slow change in phase which one often encounters or what one might call a lag or lead of one curve with respect to the other which may accumulate through the years.

There are other noticeable cycles in the affairs of the earth, such as those noted in the outbreak of epidemics, as in the case of poliomyelitis and diphtheria. The latter disease has a well-known seven-year period. The fact that this appears to show no relation to the solar cycle of 11 years may or may not have anything to do with the argument. The Ptolemaic astronomer who in the epoch of the geocentric theory observed that the opposition of Mars occurred every 2.14 years would scarcely have thought that such a curious period had anything to do with the earth revolving about the sun in exactly one year. From the point of view of modern planetary theory, we know that it is the combined motion of the earth around the sun once a year and the similar journey of Mars about the sun once in 1.88 years that is responsible for the synodic period of Mars of 2.14 years' duration. If, therefore, some organism producing human epidemics has a life cycle different from that of its host, one or the other of these factors might vary with the 11-year solar cycle and yet give a combined result of an approximate 7-year period. This in itself is, of course, no argument for the solar effect upon disease outbreaks, but merely calls attention to the fact that a lack of correspondence in the duration of such cycles with the solar cycle is no ground for rejecting such connections.

It is interesting to speculate on the possible ways in which the variation of solar activity may affect the sun's radiation, which in turn directly or indirectly has its effect upon vegetation and possibly ultimately even man's behavior. At the Smithsonian Institution in Washington, at the Mayo Foundation in Rochester, Minnesota, and at the Boyce Thompson Institute for Plant Research at Yonkers, New York, many interesting experiments have been made and are being made that have shown how the behavior of growing plants responds to the particular wave-lengths of light that are utilized in the experiments. The exposure of lettuce seeds to sunlight prior to planting appears to be very necessary to their germination. Apples may be artificially ripened by an extra dosage of ultra-violet light, giving that lustrous redness to the skin so desirable for the fruit vender. Young tomato plants, on the other hand, wither and die under exposure to the ultra-violet light from the mercury-quartz lamp.

The effect of ultra-violet light as a prevention of rickets in animals is well known. Is it possible that we shall yet find that there is a relation between the quality of sunshine and the anti-rachitic vitamin D produced in plants? It has been found that the tissues of plants which ordinarily have little or no rachitic value are rendered more potent by irradiation from some source of ultra-violet light. An extra dosage of this ultra-violet radiation, if not exceeding two minutes, is followed by an increase in the amount of ash, calcium and phosphorus in the leaves of certain plants. Not all plants, however, respond in the same way. Cabbage, a vegetable completely lacking in anti-rachitic properties, has shown no response to such ultra-violet treatment. On the other hand, alfalfa grown in Arizona and cured in bright sunshine possesses a potency that is not found in the same plant cured in darkness. It would appear that vitamin D or the all-essential ergosterol is increased by exposure to ultra-violet radiation. Ultra-violet light from the sun, however, is not an unmitigated blessing and an over-dosage of sunshine may be injurious to certain sensitive plants.

Is it possible that changes in the amount of ultra-violet and sunshine, which have definitely been measured and found to vary with the sun-spot activity, may be responsible for slight changes in the character of the crops? May it be that we shall sometime discover vintages in food as well as in wines due to changes in nature which are, as yet, not under our control? While, as we have mentioned, ultra-violet light is stimulating to seeds, it is the green part of the solar spectrum which appears necessary to the normal growth of the seedling and the manufacture of the chlorophyll so characteristic of green plants. It appears to be the visible region of the solar spectrum and the near but not extreme ultra-violet that enter into the process of photosynthesis. Just what effect small variations in the quality of sunshine may have upon the production of all the various vitamins that are essential to health and happiness we do not know.

Medical science is beginning to find a connection, however, between the vitamins we eat and our physiological behavior. It would not be surprising to find through further investigation that the sensitive ductless glands upon which our temperaments and moods appear to depend are affected by the vitamins in the foods we eat and the degree or quality of the penetrating radiation to which we are subjected. Perhaps some day we shall find that the psychology of the human race passes through periods of optimism and depression in some subtle way that depends upon changes in our terrestrial environment for which changes in the sun may be the ultimate origin.

If such is the case, then the rather fantastic idea that sun-spots may have something to do with economic cycles, as was so seriously proposed some years ago by Jevon, may have some foundation. When one examines curves of business activity such as those compiled from Dow-Jones averages or those of Colonel Ayres, of the Cleveland Trust Company, one is indeed startled by the similarity of the variations in the world economic situation and the activity that has been taking place on the sun during the last decade. The fact that the last sun-spot maximum coincided with the peak of prosperity in 1928 and 1929 and the last minimum occurred at the bottom of the depression in 1932 and 1933 may be a mere coincidence. When, however, one examines data further back in history, it is interesting to note that 5 of the 7 greater depressions have followed in the wake of maximum disturbances on the sun. The sun-spot maximum in 1884 was followed by the depression of 1885. The next maximum in the solar cycle was reflected in the depression of 1893 and 1896. When the sun-spots topped their market again in 1906, it was but a little more than a year before the panic of 1907. Four and one-half years after the sun-spot maximum of 1917 came the depression of 1921 and 1922 The depression of 1903 and the pre-war depression of 1914, however, find no counterpart in the solar curve. Of course, certain circumstances in world affairs may have complicated the economic curve a bit and delayed or accelerated here and there certain terrestrial events over the sun's wishes in regard to the matter.

Seriously, however, human psychology and results of human behavior do respond to environment and probably to the condition of the atmosphere we breathe. We have all noticed how on some bright sunshiny days we feel ambitious, energetic and glad to be alive, while during prolonged, dreary rains we often become discouraged and inefficient in spite of our best efforts. Perhaps the weather was to blame and perhaps the character of the air had something to do with it. Every day the electrical condition of the atmosphere is being measured at the Department of Terrestrial Magnetism at the Carnegie Institution in Washington. It has been discovered that the number of large ions increases after sunset, whereas the number of small ions increases during the early morning hours. Perhaps here is a difference in the quality of day and night air of greater importance than humidity. Recent experiments at the University of Frankfort by Professor Dessauer have indicated that patients exposed to air containing a large number of the positively electrified ions develop a feeling of fatigue, dizziness and headache. As the positive ions were slowly removed and new negative ions created within the air-conditioned room, fatigue and headache gave way to exhilaration. The inhalation of negative ions at frequent intervals over periods of several weeks has been found to generally improve conditions of high blood pressure in 80 per cent. of the cases. Whether the character of the ions in the lower atmosphere is materially affected by changes in solar radiation with the sun-spot cycle, we have as yet insufficient evidence to determine. The question of the electrical potential drop from the atmosphere to the ground is a subject of only relatively recent investigation. Meanwhile, researches in medical circles and biological laboratories give increasing evidence as to the electronic character of all our physiological processes.

Such speculations as those in which we have just indulged are, at present, without much scientific foundation but offer sufficient food for thought as to nourish a wholesome state of openmindedness without which scientific progress in new and untrodden fields can not be made.

Differentiating then between such facts as have been definitely established by observation from such interesting topics as those which intrigue our imagination, we may summarize briefly the present state of our knowledge as to the effect of the sun on human affairs.

(1) We definitely know of the existence of sun-spots as terrific cyclonic storms in the solar atmosphere generating powerful electromagnetic fields.

(2) Sun-spots come and go in definite cycles of approximately eleven years' duration, a fact which has been established from at least three hundred years' observations.

(3) Magnetic changes in the earth are definitely known to accompany the rise and fall of sun-spots. This fact rests upon careful observations of variations of the compass and measurements of the strength of the earth's magnetic field for over a century.

(4) Auroral displays are known by actual observation to be more numerous and more brilliant at times of sun-spot maxima That the auroral displays are due to electric discharges in the high atmosphere produced by electrified particles emitted from the sun appears to be the most workable hypothesis to account for auroral phenomena

(5) The close correspondence between the character of radio transmission and the sun-spot numbers appears to lie beyond any reasonable doubt as a result of quantitative measurements made during the last fifteen years.

(6) The theory of propagation of radio waves presupposes the existence of an ionized region of the earth's atmosphere, the ionization of which is chiefly produced by the ultra-violet light of the sun, which may be seriously modified by the bombardment of electrified particles emanating from the sun during the occurrence of sun-spots. The fact that the behavior of radio reception responds more closely to the occurrence of spots in the central zone of the sun and, therefore, near the sun-earth line is a strong argument for a theory of corpuscular emission from the sun-spots themselves.

(7) Changes in both the amount and

quality of solar radiation with the sun-spot cycle have been definitely established by quantitative measurements of the Smithsonian Institution and of the Mount Wilson Observatory of the Carnegie Institution. The Smithsonian Institution has found a 3 or 4 per cent. variation in the total quantity of radiation emitted from the sun; and the Mount Wilson Observatory has shown that the proportional amount of ultra-violet light varies from day to day and year to year, the ultra-violet light in general being strongest near a sun-spot maximum

(8) The effect of sun-spots on biological behavior appears to have been established beyond contention through the growth of trees whose ring patterns have been definitely shown by Douglass to show the sun-spot cycle through the centuries.

(9) The possibilities that the changing quality of solar radiation may affect directly the growth and character of the foodstuffs we eat and the consequent behavior of ductless glands is a problem for future investigation.

(10) The fact that one's physiological and psychological behavior depends upon the movements and charges of the ions or electrified particles in the air we breathe results from definite experiments already performed The possibility that the movements and character of these ions of the lower atmosphere change with the sun-spot cycle is at present speculative but is open for investigation.

(11) The question of the effect of the solar cycle on the weather is highly complex, but sufficient evidence seems to have been presented to give a basis for believing that storminess on the earth migrates through definite cycles, which follow in general the cycle of solar activity.

(12) The dependence of economic conditions upon weather, on the physiological and psychological behavior of man, appears to be a reasonable assumption The connection between this assumption and changing solar conditions is at present highly speculative, but may be taken sufficiently seriously as to open up definite fields of investigation.

Such of the above facts as have a definite scientific basis are sufficiently numerous to lead us to believe that the sun may have more far-reaching effects upon terrestrial affairs than we have been accustomed to suppose. Speculations are always entertaining, but if real progress is to be made, one can not overemphasize caution against drawing conclusions which scientific evidence is not sufficient to justify. On the other hand, unwarranted dogmatism as to the non-existence of some of the relationships between the sun and the earth upon which we have speculated is inconsistent with the spirit of openmindedness which looks toward the scientific conquest of the unknown.

IN QUEST OF GORILLAS

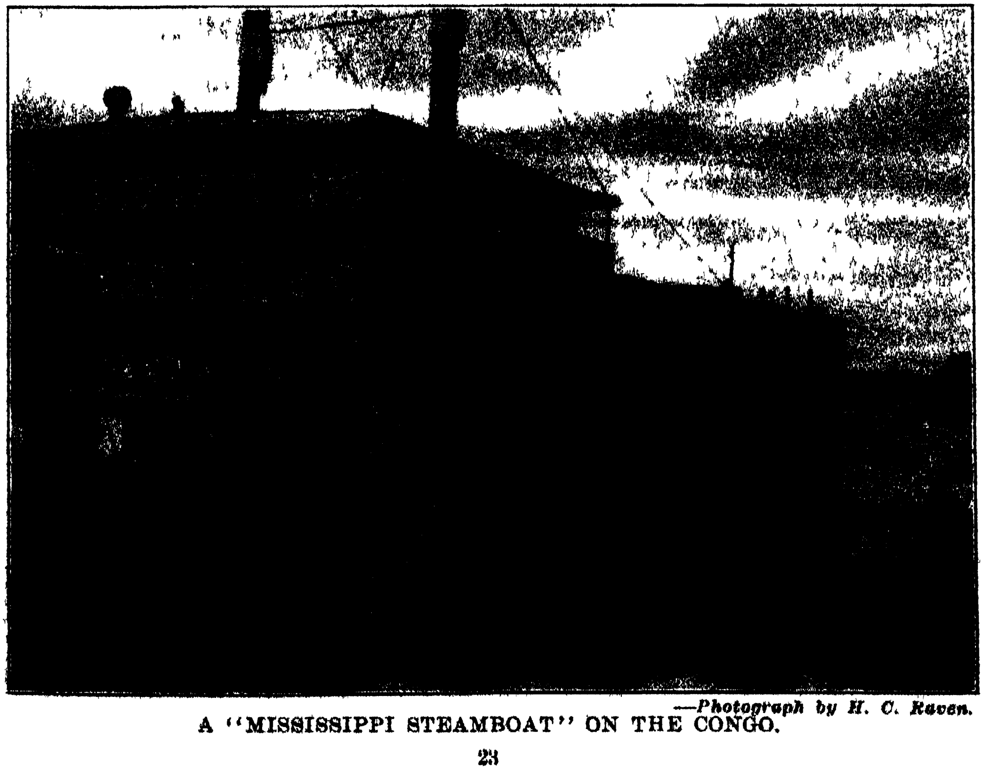
IX. CONGO QUEER 'UNS

By Dr. **WILLIAM KING GREGORY**

CURATOR OF COMPARATIVE ANATOMY AND OF ICHTHYOLOGY, AMERICAN MUSEUM OF NATURAL HISTORY, PROFESSOR OF PALEONTOLOGY, COLUMBIA UNIVERSITY

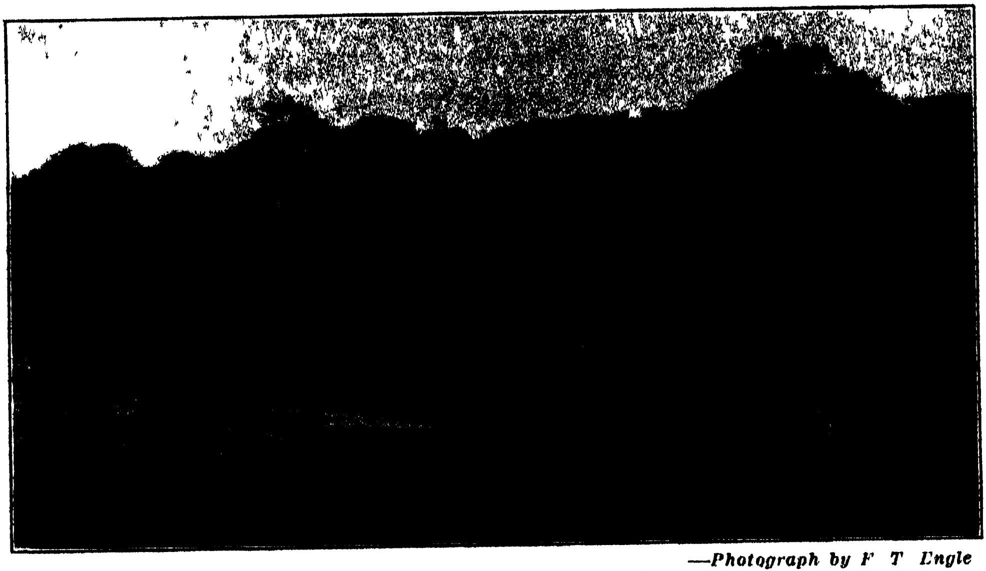
EARLY in the morning of October nineteenth we bade good-bye to Engle, while Raven, McGregor and I embarked on the big river steamboat *Kigoma* for a nine or ten days' trip down the Congo. This boat was a stern-wheeler made in Pittsburgh, Pennsylvania, after the pattern of the big boats on the Ohio River, but the superstructure had been built by the Belgians. It was very shallow and broad and could come so close to the bank of the river that only one or sometimes two long planks were necessary for a gangplank. As on the Lualaba River, landing was effected after two powerful blacks had plunged into the river with steel cables, one at the bow and one at the stern, and after swimming to the bank had passed the cables around some stout trees.

The river below Stanleyville widened out and was dotted with islands. Tributaries flowed into it at frequent intervals. The jungle seemed to differ from that on the Upper Congo (Lualaba) in the abundance of rattans, which are semi-parasitic palms that have become like vines, with long leaf-tendrils that cling to the other trees. Much of the jungle looked as if it were subject to occasional



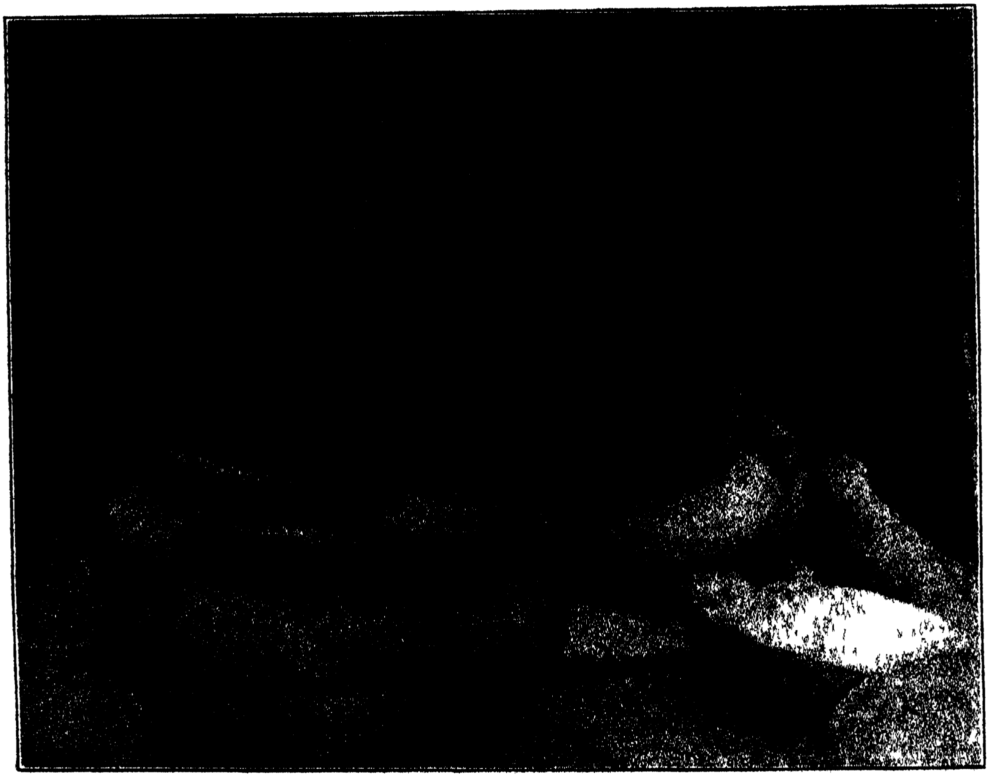
—*Photograph by H. C. Raven.*

A "MISSISSIPPI STEAMBOAT" ON THE CONGO.



—*Photograph by F T Engle*

AT THE EDGE OF THE JUNGLE



—*Photograph by E. T. Engle.*

TURNING POTS BY HAND.

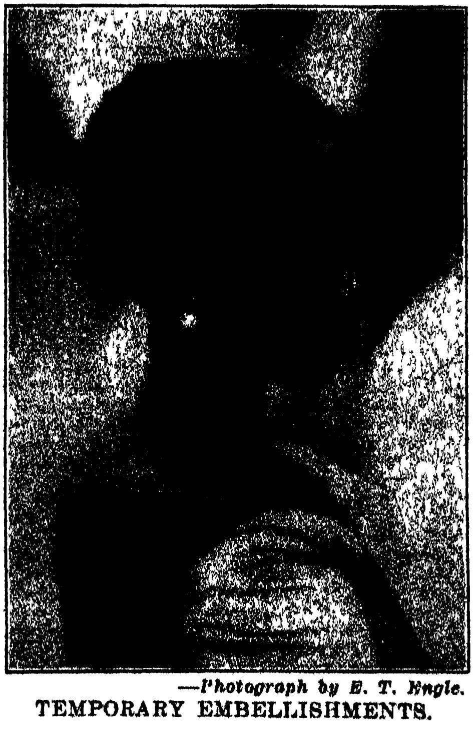
flooding. With our field glasses we could watch the many kinds of birds in this forest, but hippopotami and even crocodiles were seldom seen by any of us. Every few hours we stopped at a village to take on wood and late in the afternoon we would tie up at some town or village for the night.

At the wood stations the people were fairly primitive, living in oil-palm houses Here we could see an amusing *mélange* of nearly naked savages and a few sophisticated and superior persons with at least parts of white men's clothing. At one village, strung along a high bank for perhaps a third of a mile, a native chief, riding a nickel-plated bicycle and attired in white duck suit and sun helmet, rode parallel to the steamboat the length of the village, bowing grandly to the admiring blacks that swarmed on our main deck. There were also large towns with many *magasins* or trading shops, where the native products were bought and European-made merchandise sold by great companies that have stations all over the Belgian Congo.

At Basoka (October 20) a town where "all the world" was gathered to see the steamboat come in, I had the opportunity of observing a characteristic incident of the native folk ways One family of nearly naked savages had come up in a canoe to buy or sell or merely look on They had drawn up the canoe on the bank and had left in it a very tiny naked boy to mind his baby brother. It was amusing to see how faithfully he held the baby on his lap and acted as nurse to the rather fitful infant. When the whistle blew the baby began to bawl, but his gentle efforts to quiet it were soon successful.

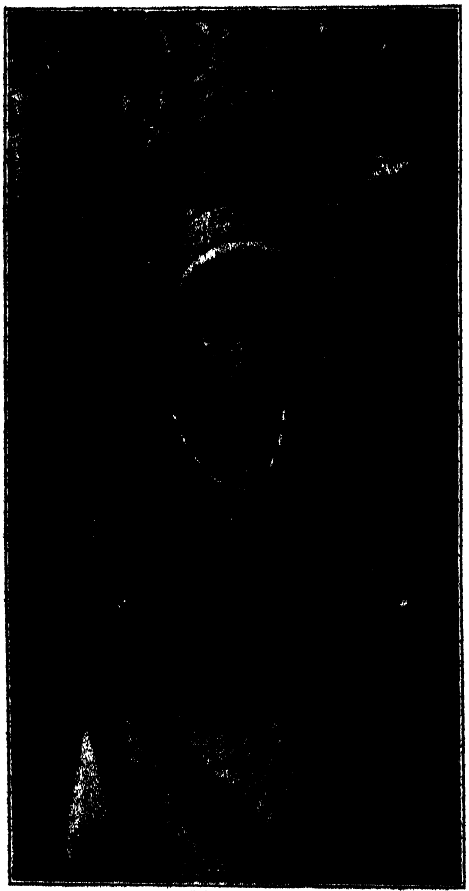
Among the crowd on the bank at another town, a boy of perhaps nine was making a determined and insistent attack upon a somewhat larger boy, punching him in the face and body. One man tried to stop the aggressor, who broke away and pursued his retiring opponent.

—*Photograph by J. H. McGregor*
A NEGRO ALBINO.



—*Photograph by E. T. Engle.*
TEMPORARY EMBELLISHMENTS.

Then another man tried to stop him, and then a woman, with as little result, the attack and retreat lasting until the combatants disappeared in the crowd. None of the adults seemed angry and they did not jabber as much as they would ordinarily. A fellow passenger who knew well the ways of the natives told me that very likely the persons who tried to stop the boy were relatives who did not wish to be disgraced by his unseemly behavior, or who possibly knew more of the merits of the quarrel than we did But, my informant said, if the boy is really a persistent trouble-maker, severe measures will be taken with him. First, his uncle and several other men may force him to run a gauntlet, inflicting a severe beating upon him. If after this punishment he later becomes known as an incorrigible, he will have red pepper rubbed into his eyes. So here for a moment the veil was lifted upon the lurking ferocity of the ordinarily genial and lŏng-suffering natives, who in many parts of Africa inflict a most terrible form of mutilation upon girls at puberty, in the name of old custom and religion.



—*Photograph by H. C. Raven.*
PERMANENT EMBELLISHMENTS.

At one town we had the pleasure of seeing a baby chimpanzee playing on the front lawn of a pleasant villa, who did not hesitate to make friends with the strangers. His very lively, almost aggressively friendly disposition was characteristic of his race and in wide contrast to the lethargic movements and reserve toward strangers of many young gorillas.

Among the crowds of interested black spectators was a Negro albino, a most unholy-looking individual with pale and yellowish-pink freckled skin, unpigmented iris, squinting eyes and light hair. He was one of several which we saw in the Belgian Congo. Beautiful brown skins of slightly reddish tinge seemed to us far more abundant than in the Kivu region, and we did not know whether this was due to the infiltration of white blood, which on the Lower Congo River must date back several centuries, or was merely an expression of the astonishing variability of the Negro race, as it was often coexistent with purely negroid nose, lips and hair.

As Lisala (October 22) we saw a large blue butterfly with very long wings and bird-like flight. Here we climbed a very high bank, including long flights of steps, to what was at one time the level of the river, and from the top we could look over to the far-distant bank of the other side, with many an island and channel in the present flood-plain. In a long walk through the native town we saw several little girls making garlands for each other; they looked especially charming. Then we saw and photo-

—Photograph by J. H McGregor.

A WOOD VILLAGE

graphed an old woman, bending under a heavy load. She was adorned with elaborate patterns of wart-like cicatrices, arranged in neat rows and curves on her forehead, nose, cheeks, breast and abdomen. Strange to say, the general effect was rather decorative. Two young girls with similar adornments were next glad to pose for their photographs. Then we went on down a long mountain path to a stream where native women were treading and squeezing out the oil from the nuts of the oil palm.

At one village where we stopped to take on wood (October 24) I was galvanized by the sight of a large living *Protopterus* in a wooden bowl in front of a native house. This thrice-venerable lung-fish is the lineal descendant of the fossil lung-fishes of the Devonian period, rocks from this period being provisionally estimated to be about three hundred million years old by the "radium method" of the physicists. Its great geologic age had not mellowed its disposition, however, as it bit viciously at an admiring finger. The woman that owned it, too, crabbedly refused to be tempted by francs and curtly dumped it into the pot. Almost immediately afterward my temperature went up another degree or two at the sight of a dead *Polypterus*, like the one already eulogized in these pages. After returning to the steamer I found one of the *parvenus*, or recent intruders among these ancients, in the form of a good-sized carp of the genus *Barbus*, representing a prevailingly northern family, which according to the best evidence at our disposal could not boast of more than a million or two years of residence south of the African Mason and Dixon line.

Another relic of vastly more ancient

times was a six-inch centipede, which insisted on crawling up Mr. Raven's leg while he was taking a shower bath in a dark cabinet. Perhaps the cold water made the beast sluggish, for it did not attempt to bite. Raven calmly brushed it off and then called the deck steward to come and remove the wooden grating under which it was hiding. The darkey very gingerly dragged it out with a stick and it was lost to science by being thrown overboard

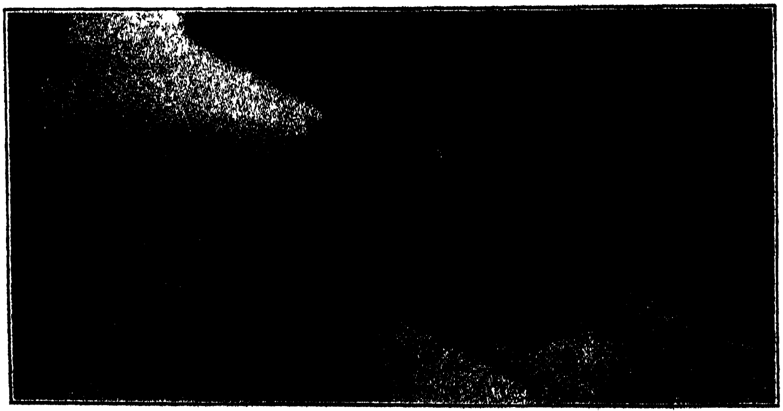
We found Coquilhatville (October 25) to be a very progressive and smart-looking modern city with a large native settlement, both of which we viewed on our auto ride to Eala, which is one of the great botanical gardens of the world. For mile after mile we drove through plantations of coffee, cacao, rubber and many other trees, passing at the end through a long tunnel formed by closely over-arching bamboos The catalogue of this Botanical Garden includes several hundred species of trees, bushes and plants, which can be furnished in quantity as slips, seeds or cuttings to any part of the Belgian Congo. This enables the Belgians to plant thousands of trees along the automobile roads and to raise great crops of wood from such rapidly growing trees as eucalypts, which are planted in groves in formerly devastated areas.

On the very high bank of the river at Lukolela (October 26) there were extensive formations of laterite, a kind of reddish "pudding stone" of quite recent solidification, very abundant in many parts of Africa and covering the older geological formations. Here also, as in so many other regions, many of the oil palms bore abundant nests of the bustling yellow and black weaver-birds, who manage somehow to weave the tough, pouch-like nests and line them with fine material.

As we went on down the river below Coquilhatville (October 27) it first widened out greatly, being almost lake-like, and then gradually narrowed again as it approached the "water-gap" leading to Stanley Pool.

Below Bolobo an insane passenger, a sick man on his way to Belgium, locked his poor wife in the stateroom and then leaped over the rail into the river. A boat was sent out and the *Kigoma* circled around for a long time, but only his floating sun-helmet was retrieved; the body was swept down the swift current and so far as we heard was never recovered

We were delighted to find that two of our neighbors in nearby cabins on our deck were young geologists, who had been making maps and special studies in certain parts of the Belgian Congo. One



—Photograph by the author.

CONGO LUNG-FISHES.

–*Photograph by J. H. McGregor.*
A PATHWAY AT EALA, BORDERED BY OIL PALMS.

of them, M. Lohest, was the son of the late Professor Lohest, who some years ago entertained Dr. McGregor when the latter was studying the fossilized human crania found in Belgium and France. He and the other young man, M. Staquet, helped me greatly in interpreting the geological features which I had been observing on the way down the river. For we were now (October 28) passing by great cliffs of the "Lubilache" formation, mostly buff-colored sandstones, which had been laid down presumably in fresh water in Triassic times but had been cut through by the present river in quite recent geologic times. Below Black River and above Stanley Pool the river makes a sharp swing toward the southwest as it passes through the mountains. Here at sunset one could gain a view of dark mountain wedges in the foreground and hazy barriers in the distance.

At a village some way up the mountain on the left bank in this region the headman, who wore a massive neckband of incised brass, showed us some huge clay vessels which he said were filled with "goobas"; when he handed us some of these, we recognized the peanuts of our

—*Photograph by F T Engle*

RIVER SCENE NEAR LUKOLELA.

THE PEOPLE HAVE BROUGHT THEIR SICK FOLK TO THE HOSPITAL, LEAVING THEIR CANOES AT THE SHORE NEAR BY.

southern states, where they are frequently called by this name As the peanut is supposed to have originated in Brazil, it may have been introduced into the Congo Basin by some early slave trader or missionary.

On the morning of October 29 we passed into the great expanse known as Stanley Pool, which is flanked on the north bank by buff-colored cliffs of the Lubilache formation (wrongly regarded as *craie* or chalk by some Belgians). Kinshassa, the end of our ten days on the river boat and the largest city in the Lower Congo, is near the lower end of the pool.

At Leopoldville, which is immediately west of Kinshassa and continuous with it, we were invited by the Reverend Emory Ross to visit the American Baptist Mission. Here I saw a building which dates from Henry M. Stanley's time. Mr. Ross told me that one old Negro, now connected with the mission, had been present as a baby when there was a fight between the natives that were with Stanley and those that were opposing his advance. In this fight Stanley's men killed the men in a certain village and carried off the women, including this man's mother and himself

While staying at Kinshassa we made two visits across the river to Brazzaville, which is the seat of the governor-general of French Equatorial Africa. Here we saw clearly for the first time representatives of the tall, very black Negroes from West Africa, who are dressed in voluminous white robes. Governor Antonetti received us at his villa with great courtesy and gave us a letter to Governor Marchand of the French Cameroon, where we had decided to go in search of the West African gorilla.

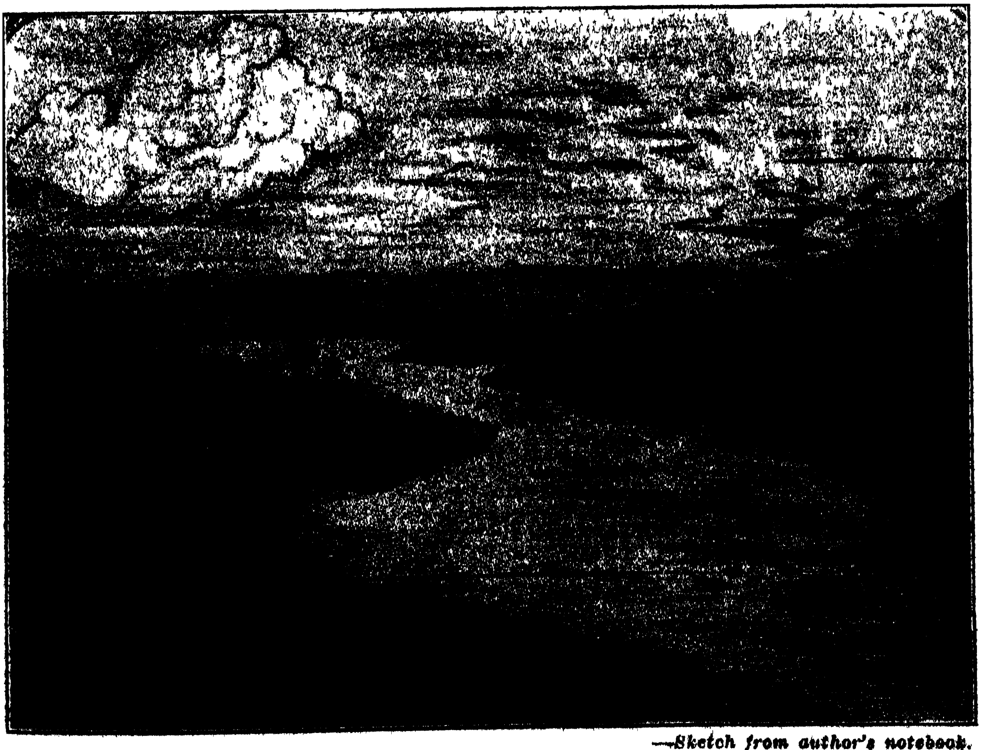
Meanwhile we had given up our plan of going back up the Congo River to the Sanga, as we learned that it would be several weeks before the next boat started and that it would be a twelve-day trip. We accordingly decided to take the "*Chargeurs Réunis*" line from Matadi up the west coast, and to get off at Douala in the French Cameroon and then go inland.

Brazzaville stands in wide contrast to the bustling Belgian cities to which we had become accustomed. It is a much older, rather sleepy place, sprawled over a wide territory. But an artist could have reaped a harvest of interesting color sketches of the natives. Their highly varicolored garments were often bleached out by the rain into pleasing soft tints, and it seemed to me that even the patterns were more reminiscent of French art and less crude and commercial-looking than those to which we had become accustomed on the Congo River.

Yellow-brown Chinese coolies working on the railroad afforded a strange contrast to the black and reddish-brown people by whom we had so long been surrounded. In Brazzaville there were more tall black men with good beards than in the Kivu region, and everywhere we received suggestions of North and West African influences.

The small ferry boats that run across the broad river between Brazzaville and Kinshassa were run by black engineers and captains; the latter seemed to be efficient in managing the boats in the river currents. On the way home from Brazzaville the sunset as seen behind Stanley Pool was so stupendous as to defy description, but it stands out in my memory as the peer of any I have ever seen, either in the tropical Pacific or in Africa.

One of our fellow guests at the hotel in Kinshassa had a large crate full of young parrots, which he and his wife were taking back to Europe. At night the crate was set on the veranda just out-



—Sketch from author's notebook.

SUNSET NEAR BLACK RIVER.

side our windows and the little dears started their all-talking performance at sunrise. As they were not English-speaking parrots I trust they did not remember any of the bad language they might have overheard, if they had stopped to listen.

At Kinshassa we left our two black boys Poussini and Musifiri with all their wages and presents, together with the passage money back to their homes on the other side of Africa. Matambele had stayed with Engle at Stanleyville. Raven rehearsed carefully with them each stage of the journey, which they learned very well as they had good memories and were by no means stupid. But as it proved impossible for us to buy the tickets in advance for third-class passengers, Raven warned them that if they wasted their money and did not buy their own tickets at each stage of the return journey, they would fall into the hands of the police They promised solemnly to follow this good advice, but Dr. Engle learned later that they were still at Kinshassa. However, in a country where so many young men wander far from home this was nothing unusual and we can only hope that their experiences with us and our letters of recommendation, added to their native talents, stood them in good stead in getting places as cook and general servant, respectively.

From Stanley Pool to Matadi the Congo is unnavigable for large boats, since as it descends from the continental plateau to the coastal plain it abounds in rapids and falls. Hence the vast inland waterway of the Belgian Congo can at present be linked to the seaboard only by means of a railroad which pierces the crystalline mountains that mark the western bulwarks of the continent. Accordingly at Kinshassa we took the train for a long day-and-night ride over the mountains to Matadi on the Lower Congo, the Belgian port for ocean-going vessels. We stopped for supper at Thysville in the mountains, a town named for General Thys, the engineer who forced the railroad through this desolate country at the cost of fearful mortality among the workers. Here the finely plaited rocks of the Lower Congo system are exposed, and it was a great satisfaction to have many new glimpses into the foundations of the continent.

(A further article in the series entitled "In Quest of Gorillas" will be printed next month.)

THE JIBARO, AN AMERICAN CITIZEN

By Professor **WILLIAM H. HAAS**
DEPARTMENT OF GEOLOGY AND GEOGRAPHY, NORTHWESTERN UNIVERSITY

THE Jíbaro is an American citizen of whom relatively few Americans are aware and in whom they may take little pride. Although an American citizen, he knows not the meaning thereof and may not even be aware of the high honor thrust upon him by official decree How should he know and why should he be thankful, never having been taught nor affected by the transfer of his allegiance in which he took no part. In his own circumscribed and prescribed thinking he is the same Jíbaro, no matter what the citizenship, no matter what the form of government or by whom it is administered. He doesn't bother about citizenship; it is food that he wants Life to him goes on in the self-same, humdrum way with no vision beyond that of his ancestors generations and generations ago. He, in a measure, is to Puerto Rico what our "Southern Mountaineer" is to eastern Kentucky. He, like members of other isolated groups, has become lost in the hills, with little contact economically or politically with world movements. In fact, history has ignored him and passed him by, as have also the comforts and conveniences that make the life of the average American so rich and full. All this has left him in his loneliness of thought and action and misery.

The Jíbaro is very definitely a product of his environment He is a little more. He is not only a part of all that he has met but also a part of Indian, Spanish and Negro cultural elements fused into one Were it not for the fact that he makes up the bulk of the population of Puerto Rico, he might be passed by as an oddity, a misfit, meriting only a dilettante interest, as in the main has been

AVENIDA PONCE DE LEÓN LEADING PAST THE CAPITOL
THE BEAUTY OF THE ISLAND IS IN SHARP CONTRAST WITH THE MISERY OF THE JÍBARO.

accorded our Southern Mountaineers. There is, however, a distinct difference between the two groups. Although our mountain people have been looked upon as backward, with a colorless existence broken by moonshine and feuds, their plight has aroused some interest and attempts have been made to improve their economic and social outlook. Educational institutions of various grades, active in the region, are monuments to the milk of human kindnesses of a few. The Jíbaro in contrast has not had even this aid. He, in the main, has had no stimulus from the outside and, what is more, has been ruthlessly exploited by those privileged to help him.

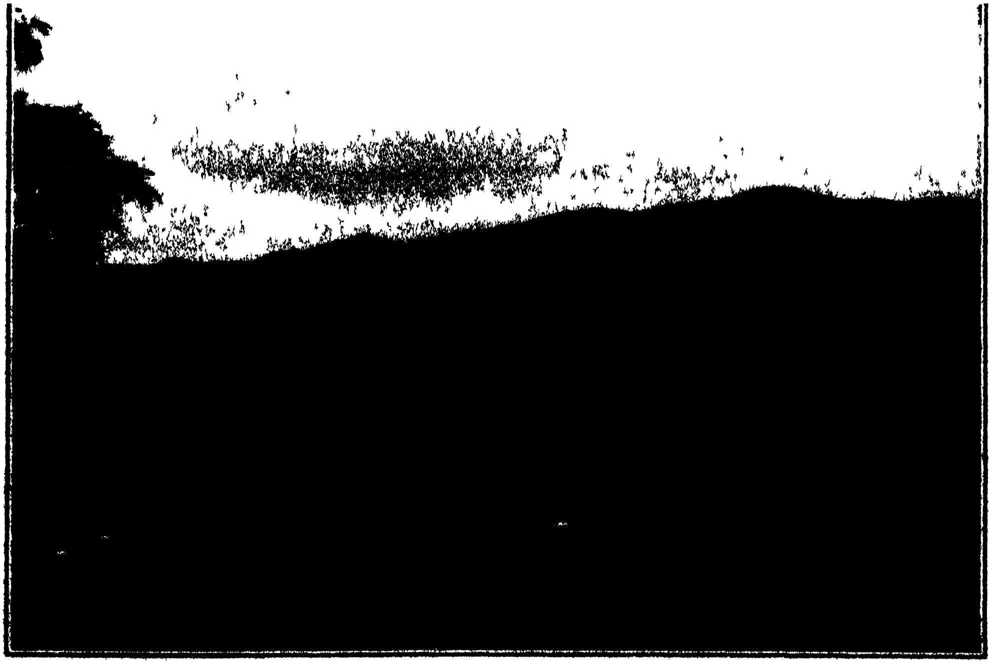
The name Jíbaro (Hé-bä-rō) is one given long ago in Puerto Rico to a person living in the country. At present he is an ignorant, superstitious, pathetically poor country peasant on American soil. A century or so ago, the name was spelled Xívaro, but the meaning was the same. In the appellation there is no connotation of disrespect nor does it carry any stigma. It is accepted by these people with equanimity, and they may even name the little roadside stand *El Jíbaro*. Cultural influences on them have been extremely limited. The church, as in so many backward communities, has had little influence, perhaps more than appears on the surface. The Catholic church, always a potent factor in the spiritual life of primitive Latin American people, has done little in advancing their cultural evolution. The Protestant churches, beginning about the time of the American occupation, have done some creditable work, but little or nothing in an important way where most needed. During this American period, the Catholic church has also been much more active, both groups helping the people economically as well as trying to take care of their spiritual welfare. The work done, commendable as far as it has gone, has been in general negligible, ameliorative rather than constructive.

The Jíbaro, however, has been undergoing a genuine metamorphosis during the last few years, and it is doubtful whether he ever again will be satisfied to go back to his former status. A new outlook is being brought to him directly and indirectly through the PRERA, as the Puerto Rico Emergency Relief Administration is known to him. Perhaps no political activity has ever done so much for a people in so short a time. The name Prera will probably live long after the actual P-R-E-R-A is no more.

The training and education received through the various governmental agencies, especially the CCC camps, have been the most vital element that has ever come to the Jíbaro and are bringing to him a new point of view, a new lease on life. The old established order is receding rapidly. Unquestionably, at no time in the past history of the Jíbaro has he been so much of a personality as now. The recognition received has given him a sense of personal values which is new to him and which he can not be expected to relinquish graciously. He is beginning to see visions, and old and young alike appear in the public demonstrations for a place in the reconstruction of all, not part, of Puerto Rico. During the boom days, many migrated to the cities and added their quotas to the slum sections where they have eked out a precarious existence, in many cases in poverty even greater than they had endured in the rural districts. These migrants, also, are united under the same magical name of *Prera,* which to their simple minds promises so much. The word *habilitación* is known to all and is a common one among them. The greatest of all demonstrations known in the capital city was held on Saturday, July 6, 1935. Banners bore: "The women protest against the legislature." "Hunger demoralizes a people." "Legislators, how long will you abuse our patience?" "Down with the large corporations and rich land-owners." "Give us a New

"EL JIBARO"—A ROADSIDE STAND

SELLING BARBECUED ROAST PIG. THE JÍBARO CHILDREN ARE OF THE BETTER TYPE, BUT THE SPINDLY LEGS OF THE BOY INDICATE THE LACK OF PROPER FOOD.



FARMING ON THE MOUNTAIN SLOPES

A TYPICAL SERIES OF HILL SLOPES WITH THEIR CULTIVATED FIELDS UP TO A SIXTY-DEGREE SLOPE WITH NUMEROUS DWELLINGS, A FEW OF THEM SHOWING AS WHITE SPOTS.

IN THE CARIBBEAN NATIONAL FOREST IN NORTHEASTERN PUERTO RICO. TRUNKS OF TREES ARE SHOWN COVERED WITH ORCHIDS, PENDENT LIANAS AND TREE FERNS IN BACKGROUND.

TRUCKS ON A BUSY STREET

A PART OF THE CONGESTED WHOLESALE DISTRICT OF SAN JUAN, WHERE, WITH PONCE AND MAYAGUEZ, THE WEALTH IS CONCENTRATED.

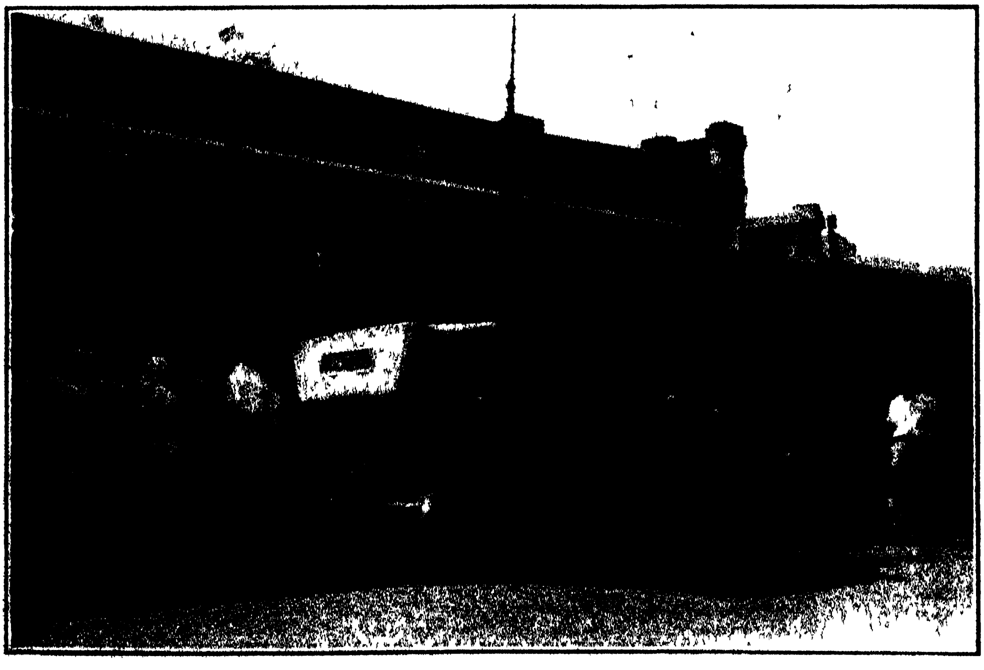
Deal." "President Roosevelt is a more patriotic Puerto Rican than our legislators." And so on

Physically and culturally as well, the present Jíbaro is a product of four centuries of amalgamation in the New World and his foundations were laid more than a century before the Pilgrims saw the shores of the New World. In 1509 Ponce de León, with twenty men, founded the settlement of Caparra, which later was to become San Juan, the capital city of the island of Puerto Rico. Two years later, in 1511, there were 200 Spanish male adults, but in that year eighty of them lost their lives when the natives rose in open rebellion. In this rebellion a great many natives also met death and probably not more than some 20,000 remained, all of whom in some form or other were distributed among the conquerors according to the *repartimientos* system, an effective way of enslaving a whole people by official decree. Other uprisings among the Indians occurred, but all failed ignominiously and many of the natives left their valley habitat and fled into the more inaccessible mountain areas; some futilely even left for other islands

Under such a relationship between the two races, it was only natural that the Indian women should soon greatly outnumber the male population, for, as providers, they did not risk their lives in warfare. Furthermore, as the Spaniards were not colonizers, but adventurers, *conquistadores*, many of them members of the nobility who wished only to recoup dwindling fortunes, they did not bring their families with them. As history shows over and over again, the Spaniard in the New World had no scruples in cohabiting, more or less promiscuously, with Indian women, and a transfer of allegiance by the Indian woman to some white male did not work any particular hardship, as her lot in many cases was greatly improved. Thus the inevitable process of amalgamation was begun early and the beginnings of a Jíbaro class were laid shortly after the discovery of the New World.

In 1528, twenty years after Ponce de León had landed, the excessive numbers of white males in the New World caused the king, in order to increase the Spanish population in the New World, to issue an edict for all Spaniards to marry under pain of forfeiting lands and mandated Indians. History does not say how much effect this edict had, but a census taken three years later by the governor reported 71 Spaniards married to white women, 14 married to Indians and 298 unmarried.[1] Even at this early date, 14 Spaniards had been joined to native women by the rites of the church. The number given as unmarried did not exclude those only consensually married or those who had one or more concubines or lived in a state of free love. The latter groups were the ones with the most numerous offspring. Among the Negro slaves, only three couples were reported as married, the males outnumbering the females three to one. The free but mandated Indians numbered 473, Indian slaves 675 and Negro slaves 1,523. This commingling of the three races and the rapid decrease in the Indian population are most amazing in view of the fact that they were brought about by such a small number of whites in the space of only twenty short years. The Indians, reported in the beginning to be as numerous as bees, twenty years later numbered only 1,148. At this time the Negroes already outnumbered the Indians by a fourth and those who brought about this change, the whites, were outnumbered by the other two, ten to one.

This was the set-up for a Puerto Rican



THE MARKET BUILDING AT RIO PIEDRAS

TRANSPORTATION BY BUS IS EXTRAORDINARILY CHEAP. THE JÍBARO MAY BE ABLE TO AFFORD TRANSPORTATION OF HIS PIG ON THE BACK OF SUCH A CARRIER.

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[1] Brau, "Historia de Puerto Rico," pp 70–71

race with Negro blood dominating in the coastal regions and tributary lowlands. Indian blood was most plentiful in the interior highlands and the white blood acted as an adulterant throughout the whole. It is the combination of the black, yellow and white elements in their undeterminable degrees of admixture that makes up the present complex of the Jíbaros. To this agglomeration has been added later some Indian blood, somewhat more Negro blood and, throughout a much longer period, a much greater amount of white blood. In this miscegenation, the end product thus far has been what our census of recent decades lists as "Whites," who, however, most commonly resemble the East Indian in color. Seemingly, the soft black hair, curly more than kinky, has been one of the most persistent characteristics of the Negro. This soft, even kinky hair in one of the blond type with blue eyes is not an unusual sight among the hill peoples. The combinations of all types are truly limitless. Indian characteristics as such, except for the straight black hair and almond eyes, are rarely seen, although the scraggly beard and more rarely the high cheek bones are also somewhat in evidence. The people as a whole have surprisingly long and narrow heads. In the main, however, the cultural elements which have come down through the generations are more in evidence than physical features.

Because the Negro element is much more evident in the coastal cities than in the interior, many have been led to believe that Negro blood is much more common than it really is. Slavery in the interior never proved profitable; in fact, it was never very profitable in the coastal region, except where sugar cane was the dominant crop. The country person, therefore, the Jíbaro, is freer

A SMALL SECTION OF A RECENT PARADE

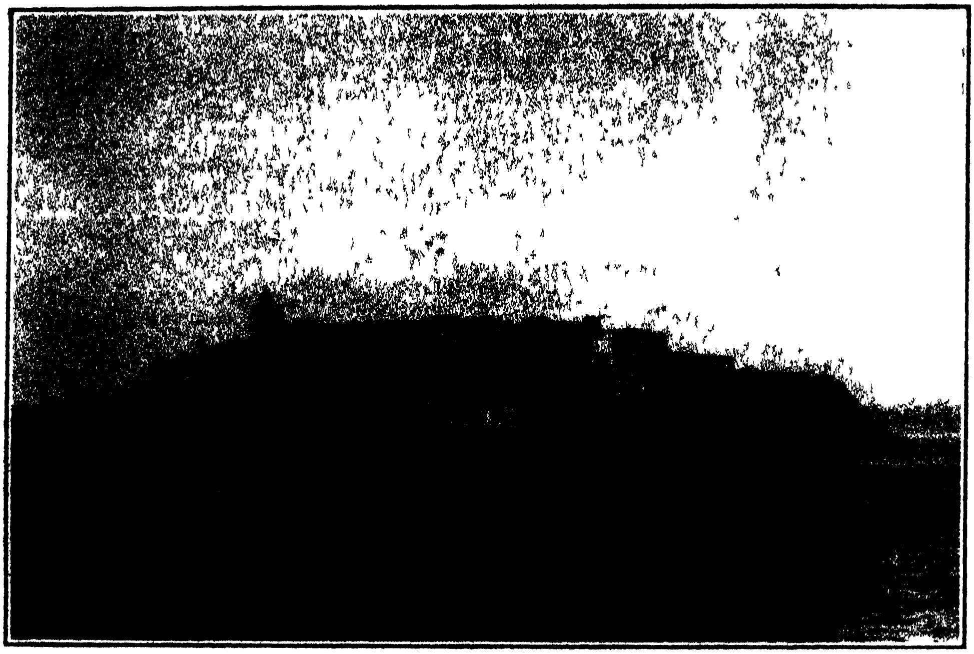
Representing every municipality (county) on the island trying to impress upon legislators the need of agrarian legislation to help the poor Jíbaro. The larger banner reads, ''To hell with the big landed estates. Return their lands to native farmers.''

THE JIBARO IS THE PRODUCER OF DOMESTIC FOODS

Upper left: Red sweet potatoes at the market, Rio Piedras. *Right:* The Jíbaro brings his pineapples to the hotel in Ponce. *Lower left:* Bags of charcoal; the transportation of goods is largely by human energy.

from Negro blood than his city cousin. Since for centuries all parts of Puerto Rico have been occupied practically to their capacity for furnishing a living, there has been little inducement for migration from place to place. Distinct racial characteristics, therefore, are noticeable in passing from one region to another. So established are these distinctions that in certain sections the marriage of cousins and near of kin is looked upon very favorably by parents, with the result that only two or three surnames may be found in such a closely built-up unit area. The pure white Spanish type is almost never found in the interior, although by far the larger number of the nearly *sangre pura* type is found in the interior. Light hair, a fair skin and blue eyes are not at all uncommon, perhaps the result of a later addition of Nordic blood.

The Indian population disappeared rapidly, in spite of the importation of Indian slaves from the neighboring islands and from even far-off Mexico. Whatever their number at the beginning, in less than half a century later no pure Indians remained, except women married to or living with the white man consensually. Since the island served as a Spanish outpost from which expeditions went out, naturally many diseases were imported into the island with a virulence, due to a lack of developed immunity, that swept the natives away as in terrific plagues. Nevertheless, the dominant cause, it seems, of their disappearance was the harsh treatment received at the hands of the white invaders. What seemed at first a fairly humane system of apportioning the natives to some sponsor or overlord soon developed into one of the most pernicious systems the ingenuity of man has ever devised for the exploitation of a weaker people, at its worst probably in the South American plateau countries. Under it the



IN THE SHADOW OF THE FORTRESS WALLS

The Jíbaro finds vacant land on the steep slopes out of reach of the sea. The extensive settlement may be noted on the right.

native became an easy prey, in his helplessness, to exorbitant taxes and tributes. The first tribute on record was imposed by Columbus as early as 1495 on the natives of present Hispaniola to the extent of gold the size of a bell on a mule and an arroba (25 pounds) of cotton, every three months for every Indian over sixteen years of age. Later tributes were much more exacting and not uncommonly incapable of fulfilment. Similar tributes were exacted from the natives of Puerto Rico. Only those who were able to escape the clutches of their enslavers left the island in order to avoid payments

The Negro, by nature, was better fitted for slavery than the Indian. This may be only seemingly so, as the immensity of the West Indian slave traffic is rarely fully appreciated. That slaves should have been imported into Puerto Rico as early as 1510 is only natural, for the home country also had its slaves. As the mines were worked out by 1536 and sugar cane was slow in developing on the island, the slave trade never was as large there as in some of the other islands. In 1860, when the last census preceding the freeing of the slaves (1872) was taken, the total population of the island was given as 583,000. The whites numbered 300,400, the free colored 241,000, and the colored slaves 42,000.[2] This census shows the white and Negro populations about equal.

The racial statistics under the United States census are only approximations to the truth in the matter of color. Negro blood is widely disseminated even among those classed as white. During the early days, the proportion of Negro blood increased very rapidly as a result of Negro importations, but by the end of the first century Negro importation practically ceased and white immigration was given

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[2] Abbad y Lasierra, "Historia de Puerto Rico," pp. 302–303.

A JIBARO CABIN ON THE ROADSIDE

MAKING ROOM FOR THE GROWING OF A FEW YUCCAS. THE LEAN TO WITH ITS DILAPIDATED AND CHIMNEYLESS ROOF IS THE KITCHEN WITH ITS OPEN PLACE FOR FIRE FROM CHARCOAL, GRASS, TWIGS OR DUNG. THE BLUR IS CAUSED BY SMOKE NEARLY ALL FOOD PREPARED TASTES OF SMOKE.

its chance to gain the ascendency again Because at present there is a general lack of discrimination in color among the lower classes in their marital relationships, a greater dilution but wider distribution of color is now most rapidly going on. The percentage of colored blood in the enumerations has been rapidly downward, from 87.9 per cent in 1530, 49.9 per cent. in 1830, to 38.2 per cent. in 1900 and 25.7 per cent in 1930. The downward trend may be expected to continue until observable negroid characteristics will disappear entirely.

In the present admixtures, white blood greatly dominates and is likely to continue increasingly to do so. Ponce, with his twenty men, soon had many additions. A year after his landing, the number had already risen to 200 male adults. By 1531 there were 869 Spanish males—women and children were not counted. Through the four centuries of Spanish occupation, the white male came and went, but more remained than left. Many of these whites were from the ranks of the nobility, most of them poor because of the primogeniture laws enforced in Spain, but they hoped to amass a fortune in the New World and then to be able to take their established places in high society in comfort. Others, as might be expected, came from other classes, former soldiers, ex-sailors, some misfits of society, and others. The royal decree of 1815 relaxing so many restrictions and offering so many new inducements commercially, brought many pure bloods with their wealth and ability from South American countries, in the throes of revolutionary unrest at that time. Within one week the arrival of 324 Catholics is recorded and also 83 "gentlemen" from Louisiana. The exodus from Venezuela was so great that during the month following the battle of Carabobo in 1821 there landed in Puerto Rico "*Ocho buques y una fragata inglesa*" all filled with "*expatriados.*"[3] Many of the more prominent families of to-day are proud in tracing their ancestry to these groups of pure whites which brought not only fresh blood of high quality but business sense and acumen.

HARVESTING SUGAR CANE

THE JÍBARO AS A WORKMAN IS INEFFICIENT. WORK WHEN AVAILABLE IS FOR LONG HOURS AND THE WORKMAN IS FREQUENTLY FORCED TO REST IN THE SHADE OF THE CANE WITH THE STATEMENT OF *enfermo*.

Here, if anywhere, is the beginning of a marked differentiation into classes: on the one hand, a high-grade cultured group in the minority but controlling the destinies of the island; on the other, the peasant group, the Jíbaro and the urban poor. His competition as a free man with slave laborers gave the Jíbaro a distinctly inferior status. He had to work, in the main, on the same basis, yet without the advantages accruing to slaves. Naturally the wages were what the rich landowner wished to pay. Since a man's existence in the tropics can be maintained on almost nothing, the landowner found it difficult to get the extra supply of labor when wanted for the wages he was willing to pay. As he was the one who made the laws, it was a simple matter to pass one that forced every freed man who did not have enough land to support a family to carry a *libreta* or certificate giving his status. If not employed, he could be arrested as a vagrant. Seemingly, this had little effect on increasing the labor supply, but it did give a distinct advantage to the employer in using the law as a threat to force the Jíbaro to work. The resultant effect, however, was to make the poor still poorer, as wages pitifully low became lower still. Well-meaning as the law might have been in the beginning, it nevertheless gave the Jíbaro a distinctly inferior status, definitely consigning him to a state of peonage, a state which he has held so long that now when in the presence of his superiors he may stand, barefooted, hat in hand, head and eyes lowered as if awaiting the order of an executioner. Such is life for one group of American citizens. This Jíbaro is, therefore, a product not only of his physical environment but also of a system which leads to class opportunities for some and to oblivion for others.

Were this Jíbaro class not so numerous, the situation would not be so appalling. At the time of the *Cédula de Gracias* in 1815, the Jíbaro population was given as 86 per cent. of the total. By 1900, the rural population, and relatively few of its number are not in the

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[3] Blanco, "Prontuario Historico de Puerto Rico," p. 63.

TWO MEN AND EIGHT OXEN OPERATE A HARROW

EVEN ON THE LARGER ESTATES THE CHEAPNESS OF HUMAN LABOR IS REFLECTED IN THE PRIMITIVE EQUIPMENT.

Jíbaro class, was 85.4 per cent.; in 1910, 79.9 per cent.; in 1920, 78.2 per cent.; and in 1930, 72.3 per cent. of the total population. This seeming decrease is not due to the rising of some above their class but to a migration to the cities with their increased industrial development of recent years. Many are forced to go to the cities, as no place for them to live is available in their home districts. In the city they build their huts on non-active land, such as on the city front, outside of the old Spanish wall or upon tidal flats. Housing conditions here are unspeakably bad.

Naturally, class distinctions between those who have and those who have not are very marked. Members of the upper class do not take kindly even to the simplest physical tasks. Their superior background, education and even moderate wealth emphasize the distinction and give them a sense of superiority, not assumed, over those who through genera-

ONE OF THE POOREST TYPES OF DWELLING

BUILT OUT IN THE SWAMP NEAR RIO PIEDRAS. THIS PARTICULAR DWELLING HAS ONE ROOM AND HOUSES TWO FAMILIES, A TOTAL OF 15 PERSONS. SUCH A SITUATION IS BY NO MEANS THE EXCEPTION.

AN IRRIGATED CANE FIELD ON A LARGE ESTATE

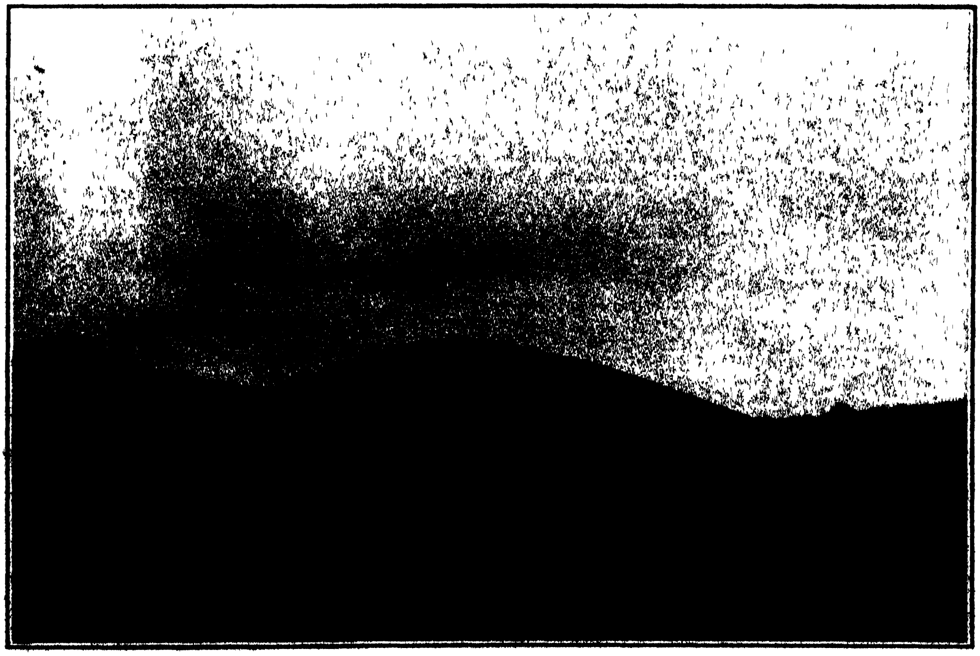
BEING GRAZED DOWN AS PART OF THE RESTRICTIONS PLACED ON CANE ACREAGE. THE SUGAR CENTRAL MAY BE SEEN IN THE BACKGROUND.

tions of need have developed a subservience hard to understand by an American. Fortunately, now there is developing a strong, energetic middle class which, largely by sheer effort and native ability under great handicaps, is forging ahead. With opportunities this group will take a major part in the evolution of the island. The bulk of the people, fully three fourths of them, however, are in the lower class—urban poor and Jíbaros. Their major distinction is landless poverty, some still poorer than others, until hunger, nakedness, wretchedness and hopelessness are their inevitable lot.

The wretchedness of this group beggars description It is difficult to escape the ever-present spectacle of poverty in going about the island. The island districts "seethe with misery." Housing facilities, no matter how makeshift, are wholly inadequate. Many are the cases where two or more families with their numerous brood occupy a small, one-room cabin. There is no place for them to build on nor anything to build with. Thus they breathe and breed in a mere animal-like existence outside the pale of the economic life of the island There is, however, little of that *verdammte bedurfnislosigkeit* sometimes attributed to tropical peoples by those who do not know the tropics The people are peaceable and kindly, ready to share their meager store with the stranger or run an errand for him, and for the most part are not resentful of those who so mercilessly exploit them.

That the Jíbaro as a workman is inefficient is only too true. It is almost inconceivable to one accustomed to good food and regular meals that the Jíbaro and members of his family have any energy left for work, on the diet conditions forced upon them. With only a cup or two of black coffee for breakfast, the worker may find it necessary to walk from his hillside cabin several miles to his work, when there is any to be had, and then work from dawn to dusk for less than a dollar a day. At noon he eats his lunch of rice or beans or corn meal in the field and at night, after working hours under a hot tropical sun, he trudges home for his evening meal, rarely with meat, and limited in quantity; then not even to enjoy the luxury of a chair or bed, but to go to sleep in a hammock, or upon the floor without undressing, only to wake up for a repetition of the previous day's experience This only for a season and then idleness with scarcely enough for a life-sustaining ration. Such is not an isolated case but the common lot of the Jíbaro. He is definitely "a man with the hoe"; the hopelessness of his situation has become almost second nature to him.

The Stars and Stripes has brought no liberty to him that he did not have under the Red and Gold of Spain; it has, in part at least, even intensified his misery. Sugar cane under the protective arms of a tariff law is by far the most profitable crop and, by and large, the only profitable export crop. Sugar lands under the control of large sugar corporations have taken the limited areas of rich, flat coastal lands and have pushed into and up valleys and over low hills and with this extension have gone the food crop lands. Where corn once grew, now cane waves its glossy leaves. The little plot once allotted to the Jíbaro for his crops is now "too valuable for an inefficient Jíbaro to putter around in." With the high density of population of 482 per square mile, no longer does the one acre in ten in food crops out of the total of 2,137,200 acres begin to supply the island's million and a half people with food. Food must be imported, and imported food is too high for the Jíbaro to buy.



FIELDS OF SUGAR CANE

THE PROFITABLENESS OF CANE COMPARED TO OTHER CROPS BRINGS ABOUT A MIGRATION OF CANE INLAND OVER THE BORDER HILLS, CROWDING CORN, THE TRUE FOOD CROP, FARTHER UP THE HILLSIDE.

The plight of the Jíbaro must be alleviated before the island can be said to be on a firm footing His number is far too large to be disregarded. No nation can advance with such a handicap, no nation can profit with its best lands exploited by foreign corporations, no matter how profitable their industry may be. The resources of the island are too limited to take care of such an over-dense population. The only hope lies in a directed policy that is free of party politics or favoritism. The shame of the situation in which we, the richest nation on earth, find ourselves must be remedied. The American people as a whole condemn whole-heartedly *"Imperialismo Industrial Norteamericano"* when it sucks the life blood of a people.

What is the solution? The more thorough the study, the more complicated the problems become. To the local politician the solution is simple enough. It is independence or at least autonomy. Even a text used in the university at Rio Piedras concludes with:

> The economic interests of New York pauperize us. The dilemma is therefore whether to take into our hands with serenity and firmness our destiny or on the other hand as mental degenerates in long-suffering agony prolonged by palliatives continue until the limit is reached in physical and moral misery, until the Island people are completely transformed into a *peonaje de parias, en hato de coolies.* Only death can save us then.[4]

However, it is the writer's firm conviction and honest opinion that to set the island adrift at the present time would be pathetically tragic to all but the politicians, who always refer to the United States as "the invader." That there has been an *"Imperialismo Industrial"* not in the interests of the people of Puerto Rico is true. That the governors general, to a very large degree, have American interests more in mind than local interests is only too true. That a few kind-hearted Americans refusing to exploit further the poor Jíbaro and his family arouses the ill will of some natives is also true. That some generously minded, far-seeing Puerto Ricans appreciate the seriousness of the situation and earnestly work for the solution of the many problems is most certainly true, and these have no general panacea for the ills of the island; some even see little light ahead. The fact nevertheless remains that on a small island with a population of one and a half million people, where less than half a million should be, with a birth rate twice the death rate and with an increase in population about three times that of the world at large, a change in politics or even independence will not furnish food for the hungry Jíbaro nor clothe his numerous brood. It would seem that the basic hope must lie in an education of the fundamental principle that when four grains of sugar are needed to keep four ants alive, a certain number of days, two grains will keep only two ants alive for a similar length of time. What, therefore, is the solution? Let who can outline a plan.

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[4] Blanco, "Prontuario Historico de Puerto Rico," p. 151, 1935. See also Barclay W. Diffie and Justini White, "Puerto Rico, A Broken Pledge," 1931.

THE NATURAL ELECTRIC CURRENTS IN THE EARTH

By Dr. O. H. GISH

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ELECTRICAL messages were first received from the earth early in the last century. Joseph Henry in America and Michael Faraday in England had made their notable discovery of electromagnetic induction about a decade and a half before. S. F. B. Morse, just a hundred years ago, had invented the first practical telegraph. Then nine years later, in 1844, the first commercial telegraph-system was put in operation between New York and Washington. In the next few years similar systems sprang up in various parts of the world. When sending messages on these systems there occasionally appeared other signals which sometimes became so frequent and intense as to seriously interfere with the sending of telegrams. A visitation of these intruding signals was usually widespread, coming at about the same time and running much the same course everywhere.

Close observation of the signals which intruded on the lines of the British system led W. H. Barlow to conclude in 1847 that they come from the earth, that such signals may be received at any time, but that they are usually not intense enough to interfere with the telegraph-service. When submarine cables came into use, disturbing signals were also noted on them at the same time as the great disturbances on land lines. Disturbances of this sort were accompanied by erratic agitation of the compass-needle, and frequently by unusual displays of polar lights. These intruding signals constitute the electric messages from the earth which are the theme of this address.

Earth-Current Storms

It was soon recognized that these signals resulted from electric currents of some natural origin which circulate in the earth, branch through telegraph-lines, and, when intense enough, actuate the receiving instruments and sometimes even damage them. The occasions when the electric earth-currents are intense and unusually agitated are termed storms, earth-current storms, not because of any connection with weather, for there is none, but rather for about the same reason that an emotional outburst is so designated.

One of the more intense of these storms occurred in 1859. All the grounded telegraph-lines of the world were apparently affected by that storm. During most of a seven-day period from August 29 to September 4 it was impossible to send telegrams. However, occasionally these currents were sufficiently intense and so steady that they could be used instead of the usual batteries for operating the telegraph-instruments. On September 2, the line from Portland, Maine, to Boston, Massachusetts, spanning a distance of 110 miles, was "worked" by the earth-currents alone, commercial messages being sent from 8 to 10 A.M. The line between Fall River and South Braintree, Massachusetts, a distance of 40 miles, was also worked in the same way. A message was also sent in this manner between Philadelphia and Pittsburgh.

In some cases the strength of the current during this storm was roughly determined. Thus it was reported that on one line in France, which spanned a distance of 600 km, the current "was equal to that produced by a battery of 800 volts.'' In Norway the disturbance to the telegraph was said to have been greater than in other parts of Europe. During this electric commotion the compass-needle was everywhere visibly agitated. At Rome it changed direction 4° 13′ in a half hour and the horizontal magnetic force changed by one eighth its whole value

Extraordinary displays of polar lights were also reported The aurora borealis was seen as far south as 18° north latitude, and at higher latitudes the brilliance of these lights was said to ''nearly equal the light of the full moon '' Except for the unusual duration and intensity of this storm and the accompanying magnetic and auroral manifestations, this description would apply to many other similar events. The association of the aurora borealis with such disturbances to the telegraph-service has been noted by telegraph operators in some parts of the United States who refer to such an event as an ''aurora on the line.'' However, the relationship is not as direct as that expression would imply.

These impulsive electric messages, which signalize earth-current storms, come only a relatively small part of the time, on the average about sixteen days a year. The rest of the time electric messages of a quite different type may be received—messages of a more tranquil nature which are patiently repeated day after day, year after year. However, the electric currents which convey them are so weak that some care is required to receive them without such distortion as may lead to misinterpretation. Because some aspects of the method of receiving these messages have important bearing on their interpretation, it seems appropriate to describe here some of the essential features of what in technical parlance is called an earth-current measuring system.

REGISTERING EARTH-CURRENTS

It was early recognized that systematic observations were required for satisfactorily investigating these phenomena. The telegraph-system by means of which the first evidence for the existence of earth-currents was obtained suggested the gross features of the arrangements used, even up to the present time. The

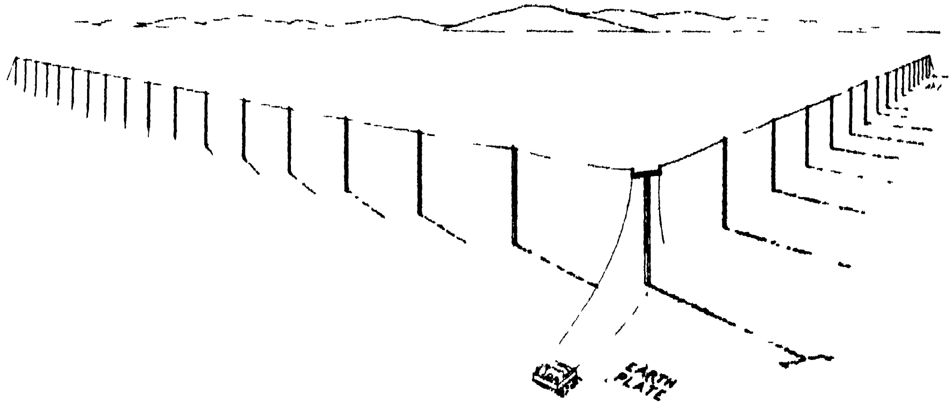

FIG. 1. THE RECEIVING ''ANTENNAE''

THE CONSPICUOUS PART OF A SIMPLE ARRANGEMENT FOR ''RECEIVING ELECTRICAL MESSAGES'' FROM THE EARTH RESEMBLES TWO TELEGRAPH-LINES WHICH EXTEND IN DIFFERENT DIRECTIONS. THESE LINES SERVE ONLY TO CONNECT THE PAIRS OF EARTHED POINTS WITH INSTRUMENTS WHICH REGISTER THE DIFFERENCE OF POTENTIAL BETWEEN PAIRS OF POINTS.

first continuous registration of earth-currents was begun at Greenwich Observatory in 1865 under the direction of Astronomer Royal G. B. Airy.

The arrangement may be described as two special telegraph-lines, with the two ends of each line connected to earth and with a galvanometer substituted for each of the telegraph-receivers. One of these lines extended from the observatory eastward to Dartford, a distance of 9.75 miles; the other from the observatory southward to Croydon, a distance of 8 miles. The contact to earth was made by soldering the wires to water-pipes. The deflections of the galvanometers were registered photographically. From the two components thus registered the direction of the earth-current and the intensity of the impelling force, the potential gradient, were determined. To the casual observer this system would seem equivalent to the most carefully installed modern one (the gross features of such being suggested by Fig. 1), but the reliability of the results obtained from the two different systems may not be at all comparable.

Systematic observation of earth-currents was apparently stimulated by recommendations made by the Electrical Congress which met in Paris in 1881. Soon after this observations were started in France, Germany, Norway, Finland, Russia, Italy and Bulgaria. Bachmetjew, in Bulgaria, used small spans, 80 to 200 meters in length. The longest spans were those in Germany, where the Earth-current Committee used two underground telegraph-cables—one extending from Berlin southward to Dresden, a distance of 120 km, the other extending from Berlin eastward to Thorn, a distance of 262 km. Registration at Berlin began in 1883 and was continued until 1891. The records for the first five years were evaluated and analyzed by Weinstein, whose report stood as the outstanding contribution to the subject for several decades. In 1910 such observations were started at the Ebro Observatory, near Tortosa, Spain, where they have been continued with but little interruption up to the present time, thus providing a body of data of much value.

The net outcome of all these endeavors, as it appeared about a decade ago, may be summed up figuratively as follows: The impulsive messages received at these different places conveyed a fairly consistent story, but the more tranquil messages were not in general agreement, only those received at Berlin and those received at the Ebro Observatory being in fair accord.

COOPERATIVE ACTIVITIES

Such was the status in 1922 when the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, in order to further its program for investigating the electrical and magnetic phenomena of the earth, installed an earth-current measuring system at its magnetic observatory near Watheroo, Western Australia. Since then this activity of the department has been extended, first by establishing another system at its observatory near Huancayo, Peru, in 1925. Later, through cooperation with the United States Coast and Geodetic Survey and the American Telephone and Telegraph Company, the registration of earth-currents was begun in 1931 at the Coast and Geodetic Survey magnetic observatory near Tucson, Arizona. Registrations were also obtained at College, Alaska, from August, 1932, to June, 1934, through cooperation with the U. S. Coast and Geodetic Survey and the University of Alaska, and at Chesterfield Inlet, Canada, through cooperation with the Meteorological Service of Canada. The data from the two latter stations are of special significance because these places are both close to the Arctic Circle

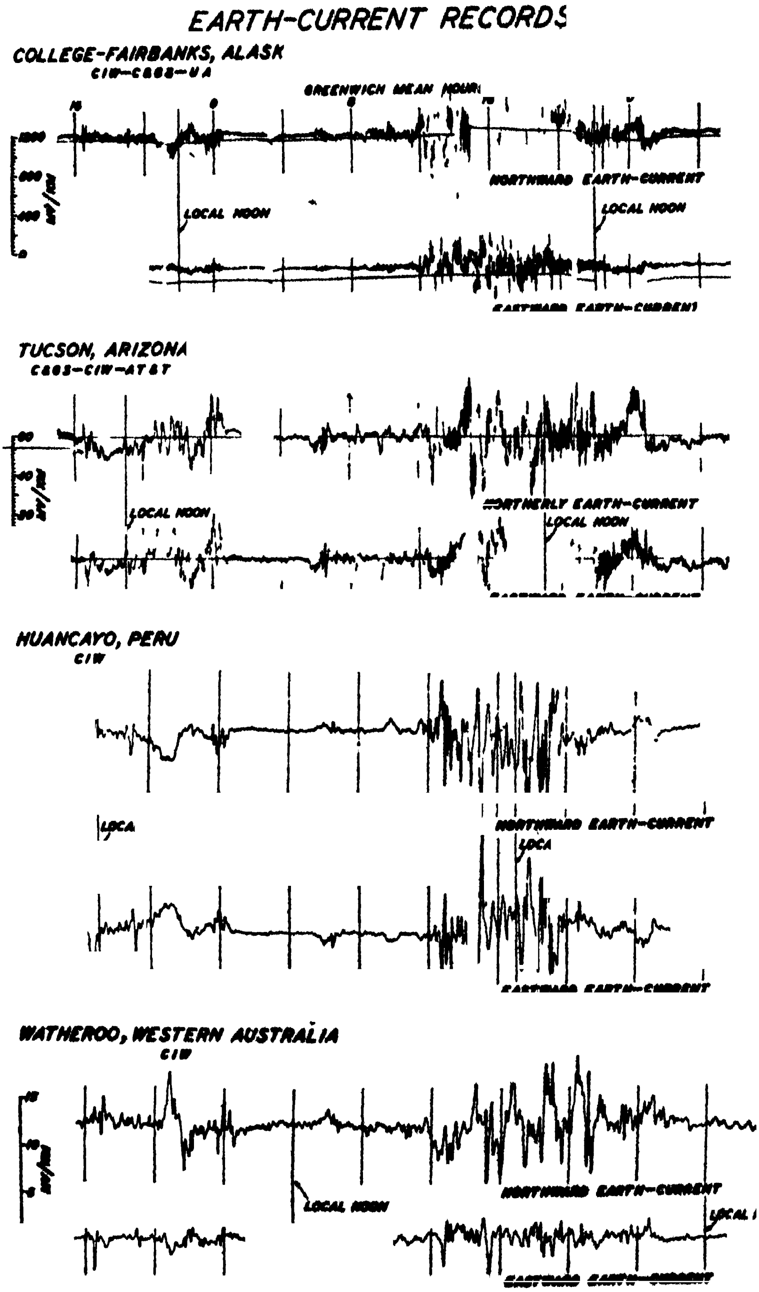

FIG. 2. IMPULSIVE "MESSAGES"

Such as these, which were received April 30 to May 2, 1933, at four places ranging in latitude from 65° north to 30° south, announce events which occur simultaneously over the entire Earth.

and because these projects were a part of that remarkable international cooperative program known as the Second International Polar Year.

Telephone and telegraph organizations have naturally been interested in these electric currents for a long time, but as a rule they have made no extended investigation of this class of phenomena. However, the Bell Telephone Laboratories have made a notable exception to the rule by conducting registrations of earth-currents during recent years at a number of places in the United States. Some systematic measurements have also been made during the past decade in Sweden. Dr. G. C. Southworth, of the Bell Telephone Laboratories, in consultation with members of the Department of Terrestrial Magnetism, planned the program and devised the means by which long-distance telephone-lines could be used satisfactorily for this work without interfering with the use of the lines for telephone-service.

The tranquil messages received in these more recent endeavors are in reasonably good agreement among themselves and also with those obtained at Berlin and at the Ebro Observatory. This outcome instills confidence in the technique which has been developed for receiving them.

STRIKING CORRESPONDENCE

The information now accumulated enables one to view some of the broader aspects of the system of electric currents which circulate in the earth. One sees that most earth-current storms which are observed in the middle latitudes occur simultaneously everywhere on the earth as illustrated in Fig. 2. Comparing these with the corresponding magnetic records reproduced in Fig. 3, one notices a pronounced similarity in the character of the magnetic and the electric records. When one is disturbed, the other is also disturbed. This, as well as the similarity in the character of the disturbances, is obviously not a mere coincidence.

Correspondence between the occurrence of auroræ and disturbances in earth-currents and possibly solar activity is also suggested by the evidence.

Observations indicate that an electric storm is likely to follow another storm at intervals of 27 days. Although for the aurora the indications are not so positive, yet there appears to be some evidence of a similar recurrence. It should be recalled in this connection that 27 days is the time required for a sunspot to rotate with the sun. A relationship is also found between the variations in earth-currents, the activity of the earth's magnetism and the occurrence of spots on the face of the sun. They all run through a cycle which has a period of roughly eleven years.

When sunspots are numerous, magnetic changes are greater and more frequent, and the earth-currents undergo more intense and more frequent fluctuations than at times when sunspots are less plentiful. From such observations one concludes that these earth-current disturbances must arise out of an influence which is capable of acting directly on the whole earth at once and that the activity on the sun in some way influences the electric currents in the earth.

When one examines the more quiet aspects of earth-currents, he finds that regular changes occur during the day. These undergo some modifications from season to season, and they wax and wane during the years. If the amplitudes of the wave-like graphs representing these changes are charted for different places and different times of the year, it will be seen that the amplitude is a minimum in midwinter, whether the stations be north or south of the equator, and that in general the values for summer tend to be

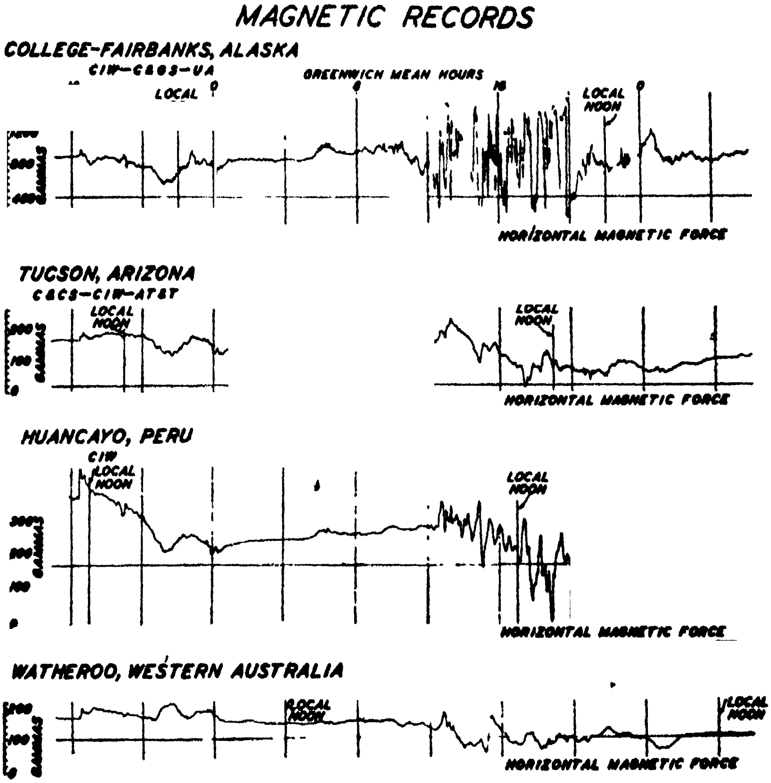

FIG. 3. IMPULSIVE MAGNETIC "MESSAGES"

THE MAGNETIC EFFECTS SHOWN HERE CORRESPOND TO THE ELECTRICAL MESSAGES EXHIBITED IN FIG. 2. THESE APPEAR TO BE MAGNETIC AND ELECTRIC VERSIONS OF THE SAME NARRATIVE.

high, yet there appears to be a tendency for large values to occur near the time of the equinoxes. There is also evidence that the amplitude of daily change varies with a period of about eleven years and that this corresponds approximately with the variations in sunspot number.

Earth-Currents and Terrestrial Magnetism

When one attempts to ascertain from the data just what relationship exists between earth-currents and terrestrial magnetism, he is confronted with some difficulty. This is especially pronounced in the case of earth-current and magnetic storms. During these storms the changes in the earth-currents are sometimes of the same character as those in the corresponding component of terrestrial magnetism, the two increasing or decreasing in unison (see Figs. 2 and 3). Then again they differ considerably in character, although the duration of the disturbed periods corresponds. If the magnetic changes were due to electric currents in the earth, then they should be roughly proportional to the electric changes; thus the graphs which represent the magnetic changes (Fig. 3) should be about the same shape as those for the earth-currents (Fig. 2).

However, if the magnetic changes produce the earth-currents, the relationship would be quite different. The earth-currents would then be roughly proportional to the rate of the magnetic changes. Thus, even though the magnetic disturbance be large, if it is changing but little the earth-current at the corresponding time would be small. A comparison of the observed storm-changes in earth-currents and in the earth's magnetism therefore seems to indicate that sometimes one relationship holds, sometimes the other.

Viewed superficially, this may be taken to indicate that part of the time the earth-currents are the cause of the magnetic changes and part of the time the result of those changes. This apparent duplicity of character, together with the inconstant nature of earth-current storms, are obstacles which stand in the way of a comprehension of them. Since it is not proposed here to venture far into the free and airy realm of speculation, we shall leave this aspect and turn to a further examination of the relation between the more quiet aspects of earth-currents and the corresponding changes in terrestrial magnetism.

The most conspicuous feature of earth-currents on so-called quiet days is the fairly regular variation during the day. Although the character of this diurnal variation varies with latitude, yet a description of that observed at Tucson, Arizona, about 32 degrees north latitude, will bring out some of the general features.

The currents there are weakest an hour or two before midnight. At midnight they flow south-westward, but steadily veer so that at 2 to 4 A.M. the flow is westward, at 5 A.M. it is northward, then the intensity increases rapidly reaching a secondary maximum at 7:30 to 8:30 A.M. when the flow is north of north-eastward. This is followed by a rapid veering to the eastward and then to the southward reaching the maximum intensity for the day at about 11:30 A.M. to 12:30 P.M. when the direction of flow is toward the south-southwest. The current then decreasing in intensity veers through westward direction at about 3 P.M., through the northward at about 4 P.M. Now increasing somewhat in intensity an evening maximum is reached at about 5 to 6 P.M., the flow then being toward the north-northeast. Then veering toward eastward the intensity decreases to almost nothing an hour or two before midnight. Thus the current runs through two cycles each day. The considerable regularity with which these cycles repeat day after day admits of their being compared quantitatively with the diurnal changes in the Earth's magnetism.

The mathematical relations between the diurnal changes in terrestrial magnetism and those in earth-currents, which should apply if the latter are induced by the former, were first derived by S. Chapman and T. T. Whitehead. The earth-current changes which they thus calculated from the magnetic changes have considerable similarity to some of those which are observed. However, there is a degree of disparity between the calculated and the observed values which can not be disregarded.

Of course the formulae were not devised to take account of those irregularities in the structure of the Earth's crust which present great contrasts in electrical conductivity and thus certainly distort the electric flow. Perhaps the most pronounced large-scale contrast of this nature is that between land and sea, the conductivity of sea-water being several orders of magnitude greater than that of land. Other currents of more or less local extent and of quite different origin may at places be superimposed upon the more general system, thus adding to the complexity.

Furthermore, one should not neglect to question the reliability of the earth-current data, provided those data were obtained in such a way as to give no criteria by means of which it may be

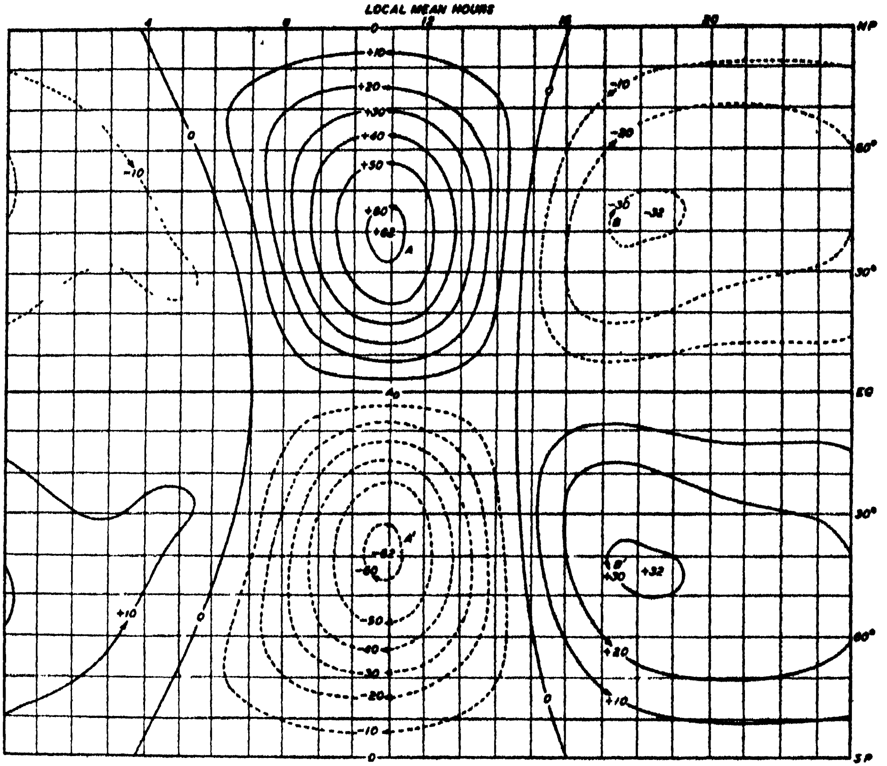

FIG. 4. ELECTRIC CURRENTS BEYOND THE STRATOSPHERE

Electric currents flowing in extensive eddies like those depicted here by Bartels would account for the average tranquil diurnal-changes in terrestrial magnetism. This current-system is fixed relative to the Sun and hence the Earth rotates within it. The Western Hemisphere is here shown diagrammatically.

ascertained that extremely local phenomena, especially such as are produced by the method of measurement, have been eliminated. Such modifying influences may account for some of the disparities. In any case, the induction theory is the only one now in sight that can claim attention.

One may therefore tentatively entertain the view that the earth-currents which are observed are in the main induced by magnetic variations, but that their strength and direction are modified in a manner which varies from place to place and which depends upon the distribution and configuration of oceans and continents as well as upon other structural features of the earth. Modifications produced in the earth-currents by the deep structure of the earth's crust may thus constitute electrical messages which contain information about conditions in that little-known region.

CURRENTS IN HIGH ATMOSPHERE

The magnetic forces which, on the view just outlined, induce the earth-currents have their immediate origin in the high atmosphere in about the same region which reflects radio waves. If a system of electric currents having the character represented by the diagram of Fig. 4 circulates in that region of the atmosphere, it would be capable of producing the daily magnetic changes which are observed at the surface of the earth.

To justify the assumption that there exists such a system of currents or any equivalent which may produce the corresponding magnetic effect would carry us beyond the scope of this discussion, since it is here desired to simply point out somewhat of the mechanism by which the electric currents in the earth may be induced. The portion of this system of currents which appears at the center of the diagram is always directly under the sun and therefore the whole system moves relative to the earth, making a rotation once each day.

The magnetic field of this electrical circulation as viewed from outside of the earth is one which in its principal features does not change appreciably with time, but, since it is moving relative to an observer on the earth, it appears to him to undergo a regular diurnal variation. This magnetic field, together with the earth which rotates within it, constitute the electric machine which generates the electric currents in the earth. Thus one might expect to find in the earth a general system of electrical circulations which is related to that represented for the high atmosphere.

THE GREAT ELECTRIC EDDIES

It has recently become possible to construct, on the basis of observed data, a world picture of the electric currents which circulate in the earth. This picture shows a number of great electric eddies (see Figs. 5 and 6). Eight of these are located in the middle latitudes, four in the northern hemisphere and four in the southern hemisphere, symmetrically

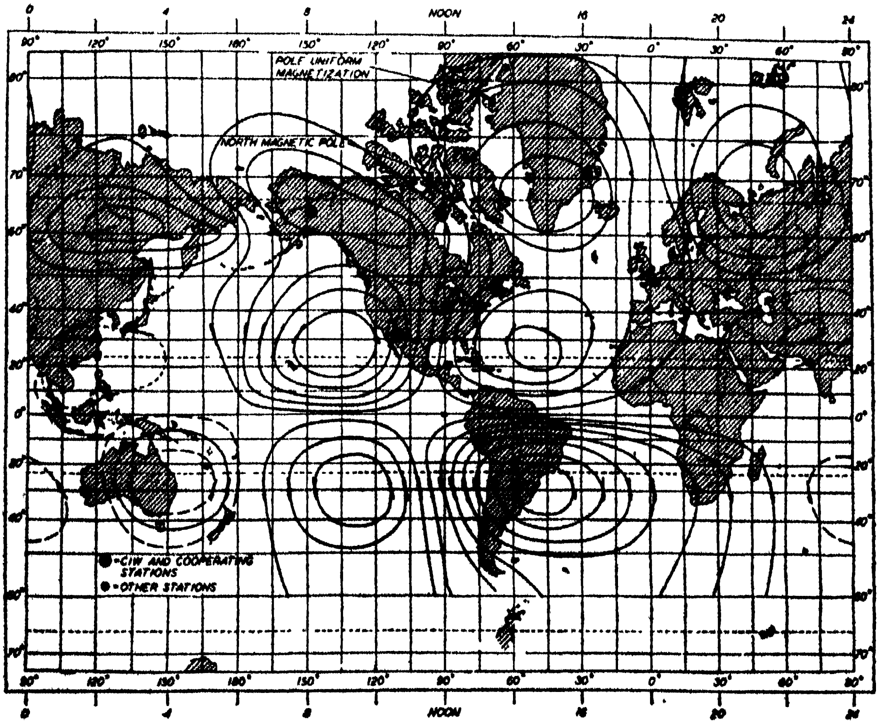

FIG. 5. ELECTRICAL EDDIES IN THE EARTH

THE TRANQUIL ELECTRIC "MESSAGES" AS INTERPRETED HERE REFER TO ELECTRIC CURRENTS WHICH CIRCULATE IN EXTENSIVE EDDIES IN THE EARTH'S CRUST. THOSE FOR THE DAYTIME OVER THE WESTERN HEMISPHERE ARE HERE SHOWN DIAGRAMMATICALLY.

placed on either side of the equator with centers about equally spaced in longitude and lying along a parallel of latitude near the tropics of Cancer and Capricorn (see Figs. 5 and 6). Four more such eddies with centers in the Arctic are also disclosed. Although there are no data to establish the fact, it seems likely that there are also four corresponding eddies in the Antarctic.

All these eddies follow the sun in such a way that there are eight on the sunlit side of the earth and eight on the dark side. The curves which outline the eddies are constructed in such a way that two adjacent curves indicate the boundaries of a tube of flow. Those tubes which are bounded by solid lines all contain the same amount of current except that in the case of the innermost curves the flow is sometimes less than that for a full tube. In order to show some of the weaker eddies it was necessary to subdivide some of the tubes. These are outlined by broken lines. The direction of flow is that of the arrows.

Current-systems corresponding to the charts which are exhibited here would completely account for the average diurnal variations observed in earth-currents

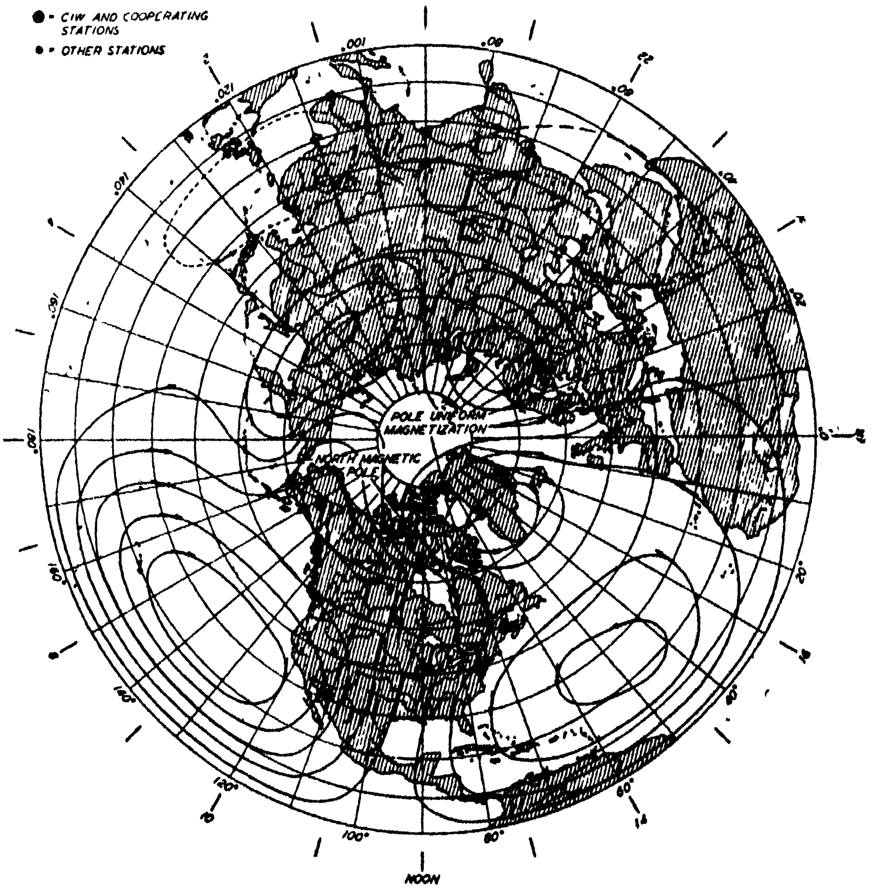

FIG. 6. THE POLAR EDDIES

The aspect of the electric eddies in the Northern Hemisphere during daytime in Western Hemisphere.

at Watheroo, Tucson and Chesterfield Inlet. Similar charts have been constructed from other sets of data; in fact, all the principal series of earth-current data have been examined in the same manner, and without exception they are consistent with a scheme having the general features here depicted.

In order that this picture may the better represent the observed facts, the tubes of flow must be regarded as very flexible, easily deformable, so that the shape of the tubes may be readily distorted and even the centers of the eddies displaced in such a way as to conform with the distribution of the electrical properties of the earth, especially of that portion which constitutes the more immediate environment of a given eddy. It also seems likely that the development and the orientation of the eddies should be in some relation to the magnetic axis of the earth. When the general aspects of pertinent earth-current data are viewed in such a perspective they will, it is believed, be seen to be consistent with the principal features of the interpretation which the charts are designed to convey.

Returning again to an examination of the charts, it will be noticed that the current in the daylight eddies is considerably greater than that in the others; at least this is true for the eddies located in the middle latitudes. The centers of the forenoon eddies of the middle latitudes are approximately on the meridian for which the time of day is 9 A.M., while the afternoon eddies center on the meridian for which the time is about 3 P.M. Considerable flexibility must be allowed for this feature. The circulation in the forenoon eddy of the northern hemisphere and that in the afternoon eddy of the southern hemisphere are clockwise, whereas in the other two daylight eddies the circulation is counter-clockwise. A similar description applies to the night-time eddies

The circulation in the eddies of the Arctic region is in the same sense as the corresponding eddies of the middle latitudes in the northern hemisphere. As these eddies move relative to the earth the direction and intensity of the earth-current at a given place change, those changes depending upon the position that place may occupy in the eddies and hence depending also upon the latitude of the place. This, then, is the world view of the gross aspects of the quiet-period earth-currents—the most comprehensive interpretation thus far made of the tranquil electric messages from the earth. It is, however, but a beginning; much deciphering remains yet to be done.

A THEORY FOR THE MEASUREMENT OF SOME SOCIAL FORCES

By Professor STUART C. DODD
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THE concept of social "forces," "acceleration" of a social process, "momentum" of a social movement and some other analogues from physics are much used in sociology with a vague meaning. It is here proposed to define them for scientific purposes as compounds of basic concepts which can be objectively observed, verified and measured. These compounds may be defined by a system of equations using, not sterile analogies, but analogous reasoning to that used in physics.

BASIC CONCEPTS

(1) *Time.* The time aspect of most social phenomena may be expressed in terms of years, Y_{11-1} (where subscripts denote terminal dates) as more suitable for social change than the seconds of physics. Other non-solar concepts of social time may describe some social phenomena more adequately (such as "adolescence," "maturity," "old age," etc.), but if they are reducible to quantitative units, they must be transposable into terms of solar years or else be something other than "time."

(2) *Population.* A second basic concept is the size of the population, P, involved in the sample studied. Its unit is the average person in that sample. While individuals in a group vary, yet for purposes of measuring social changes in groups between different dates the mean may represent each group.

(3) *"Indicia."* A third basic concept is that of the "Indicia," I, or units of the index (or "indicator") which measures any quantitatively expressible characteristic of a population. The indicator of a population, to use a term free of the narrower connotation of an economist's "index," may be a mean score on some scale, a death rate, a percentage of illiteracy, a correlation coefficient expressing a relationship of two phenomena in the population, an average expectancy of life, the per capita income of that population or its standard deviation or any other social statistic which characterizes a definite population. For each of the many types of indicators the term sub-indicator, S, may denote the status of, or the value characteristic of, one case within the series. Thus, where the indicator is the birth rate, a sub-indicator is the birth rate of Ohio within the series of the birth rates of the states. The units of such indicators may be termed indicator-units or "indicia" for convenience in dealing with them as a class, as in the compounded concepts to be defined below. An indicator, such as the Chapin scale of socio-economic status, defines a line or a continuum of some characteristic in social space; a sub-indicator, or status, is the position of a certain population on that line specified as at a given distance, or number of indicia, from the zero point or origin. The status will often be a ratio whose denominator is P, as in an average score

$$S = \frac{\Sigma I}{P} \qquad (1)$$

or a divorce rate *per* thousand, or a *percentage*[1] of foreign born. It should not be an absolute number of persons, such as the number dying in a country, as then S ceases to be so clearly a characteristic of, or related to, the whole population, P, and confusion results between S and P when they are later compounded in the concepts of momentum and force.

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[1] The indicia here are not numbers of persons but successive categories of crude two-category variables, "divorced—not-divorced," "foreign-native." Giving the two categories of this variable value of one or nothing, the per cent. divorced is the *mean* of the variable as it is the average of the values of the variable, each value multiplied by the frequency of cases at that value.

Compound Concepts. With the three fundamental types of units, years, population and indicia, further compound units may be readily derived to describe social phenomena.

Social Change. A difference in the status of a population on two different dates, i and ii, can measure the social change that has occurred in the period, in so far as the indicia are appropriate and accurate. The formula is:

$$C = S_{ii} - S_i \tag{2}$$

Velocity. The time rate with which a social change goes on may be expressed as the units of change divided by the number of years in which the change occurs

$$V = C/Y = (S_{ii} - S_i) \div Y_{ii-i} \tag{3}$$

Thus if the percentage of unemployed in a defined population fell from 15 per cent. in 1932 to 10 per cent. in 1934, the annual speed of change would be .05 ÷ 2 = .025 indicia, where indicia are percentage units.

Often the indicia are not of this static sort whose amount on a given date can be determined, but are of the dynamic units of change or process itself as, when they may be defined acts or events, in time. Thus the social process of communication may have the velocity of its telephonic component measured by defining an indicium as one telephone call. The number of telephone calls occurring for a year, then, is the velocity of this social process. Of course this is alternatively expressible as the total number of calls, since some arbitrary date, at the beginning of the year, S_i, subtracted from the total number at the end of the year, S_{ii}, giving the change or amount of the process occurring in that unit period.

This average velocity for a period between date i and date ii can be more accurate in the rare cases where a curve has been found to fit the dâta well, as then the derivatives of the equation of the curve give the velocity of change at any date within the period.

Acceleration. The velocity of social change, or the speed of "progress" may itself be speeded up (or slowed down). This acceleration, or rate of change of velocity, is measurable as the difference in two observed velocities divided by the time interval

$$A = (V_b - V_a) \div Y_{b-a} \tag{4}$$

Thus, if the quota of a Five Year Plan is increased during the period, progress in that respect may be accelerated.

Population-change. A concept, not used in physics, but which may be useful in social phenomena, is that of a population changed a certain amount irrespective of any time taken. Sometimes the terminal dates for a measurable change are not determinable. This concept of population-change is measurable as their product

$$Pc = P \cdot C \tag{5}$$

The unit of population-change is one person changed one indicium, as in a child promoted one school grade or one person changed one point of score on an attitude scale.

Momentum. Another current phrase is that a social movement "is gathering momentum" or "headway." This concept may be precisely defined as the product of the velocity of change and the population changed,

$$M = VP. \tag{6}$$

Thus a movement may increase its momentum extensively by drawing in more people or intensively by increasing the speed with which a given group is being changed. A consumer's cooperative movement may increase its momentum by either getting more people to participate or by getting its clientele to buy a larger per cent. (indicia) of all their purchases from the cooperative store. Again a mass movement for non-cooperation in India which in its boycott cuts purchases of foreign goods x rupees per capita annually among 100,000 adherents has half the momentum of one which either cuts purchases twice as much or doubles the number of adherents.

Force. A social force may next be defined as *all that which accelerates social change in a population.* It is measurable as the product of acceleration and population

$$F = AP = \left(\frac{S_{\text{iv}} - S_{\text{iii}}}{Y_{\text{iv-iii}}} - \frac{S_{\text{ii}} - S_{\text{i}}}{Y_{\text{ii-i}}}\right) \frac{P_{\text{i}} + P_{\text{ii}} + P_{\text{iii}} + P_{\text{iv}}}{2Y_{(\text{iv+iii-ii-i})}} \qquad (7)^2$$

noting that the average population of the surveys at different dates is used in case the ideal experimental technique of measuring only the identical individuals has been impossible.

Social forces may be physical, biological or social in origin, but as they stimulate the neural system in some way whether internally or externally, the unit of social force might be christened a "stim," a unit of total stimulation. A "stim" is defined as one person changed one indicium per year per year. It is thus relative to the particular kind of indicator measuring a social status or a change.[3] For some purposes the status may be compared with the similar status of another country, but for administrators the time rate of changing the status and the inertia due to the size of the population are important factors and a single measure combining all three, as force does, may be a useful summarizing concept.

Other concepts may be compounded on the model of work, energy and power. But these seem to have less utility for social phenomena. The physical terms should not be borrowed unless they offer real clarification in thinking about social phenomena.

Probable errors. The formulae for the standard errors of sampling for the above concepts are as follows;[4] derived by the usual process of differentiating both sides of equations (1) through (7), squaring, summing and dividing by N, where Y and P are considered to be constants:

$$\sigma_c^2 = \sigma_{s_{\text{i}}}^2 + \sigma_{s_{\text{ii}}}^2 - 2r_{s_{\text{i}}s_{\text{ii}}}\,\sigma_{s_{\text{i}}}\,\sigma_{s_{\text{ii}}}$$

the usual σ of a difference where σ_s may be that of a mean, (8)

$$\sigma_v = \sigma_c/Y$$

a percentage, or whatever the subindicator is (9)

$$\sigma_a^2 = (\sigma_{v1}^2 + \sigma_{v2}^2 - 2r_{v1v2}\,\sigma_{v1}\,\sigma_{v2})/Y_{2-1}^2 \qquad (10)$$

$$\sigma_{cp} = P\sigma_c \qquad (11)$$

$$\sigma_m = P\sigma_v \qquad (12)$$

$$\sigma_f = P\sigma_a \qquad (13)$$

where

$$R_{v1v2} = Rc_{\text{ii-i}}\,c_{\text{iv-iii}} = R(s_{\text{ii}} - s_{\text{i}})(s_{\text{iv}} - s_{\text{iii}}) =$$

$$\frac{-R_{s_{\text{ii}}s_{\text{iv}}}\sigma_{s_{\text{ii}}}\sigma_{s_{\text{iv}}} - R_{s_{\text{ii}}s_{\text{iii}}}\sigma_{s_{\text{ii}}}\sigma_{s_{\text{iii}}} - R_{s_{\text{i}}s_{\text{iv}}}\sigma_{s_{\text{i}}}\sigma_{s_{\text{iv}}} + R_{s_{\text{i}}s_{\text{iii}}}\sigma_{s_{\text{i}}}\sigma_{s_{\text{iii}}}}{\sigma_{c_{\text{ii-i}}}\sigma_{c_{\text{iv-}}}} \qquad (14)$$

and where $r_{S_aS_b} = r_{I_aI_b}$ the correlation between means (when S is a mean) being

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[2] Note that to determine acceleration the status of a group must be measured on a minimum of three separate dates (date ii may coincide with iii in the formula above). The velocities are average ones for the two periods ii–i and iv–iii and so are best taken as the velocities at their mid dates $\frac{\text{ii} + \text{i}}{2}$ and $\frac{\text{iv} + \text{iii}}{2}$ which are denoted by the subscripts a and b, respectively.

[3] For an example of "stims" worked out and compared in an experimental and in a control group, as well as for a fuller statement of this theory see: Dodd, S. C., "A Controlled Experiment in Rural Hygiene in Syria," American Univ. of Beirut, Syria, pp. 207–222, 1934.

[4] Acknowledgment is due to Professor T. L. Kelley for assistance in checking over these formulae and their assumptions.

the correlation between the variables (indicia) under conditions of random sampling.

Diversity of the Indicia. Since there are many kinds of index units, each appropriate for some social characteristic, there will be a corresponding diversity of "stims" and other compounded units. The compounded units must always have an accompanying specification as to the indicator involved (as well as the period and population where these are called for). "Stims" (and other compounded units similarly) will be comparable only when based on the same kind of indicia.

In order to systematize the diversity of indicia there are at least three techniques that may be of service. The first is to list all the types of indicia and attempt their classification on some suitable basis, or alternative bases, in order to reduce them to a smaller number of orderly categories. A second technique is, wherever possible, to find and express diverse indicia in common units, as percentages or indexes of a common base, as standard deviation units, etc.

A third technique is that of factorial or vectorial analysis of the observed variables (indicators) under the limited conditions where all their intercorrelations are securable. Considering each indicator as a vector, the angle between every pair of them in n-dimensional social space is given by the correlation coefficient as the cosine of that angle. Thus if two indicators, hygienic score and income, have a correlation of .50, the angle between their vectors is 60°. By determinantal algebra it is possible to transform these n vectors, representing the n observed sets of indicia, into n other orthogonal vectors (which are all mutually at right angles to every other vector), or, under certain limiting conditions, into less than n other vectors (or "general factors"), either orthogonal or oblique, as desired by the investigator. This realization of the principle of parsimony has the advantages that the observed interrelated variables are analyzed into categories or factors which fulfil the canons of classification in that they are (a) mutually exclusive (if orthogonal), (b) totally inclusive (of all the phenomena) and (c) have mathematically defined boundaries. The disadvantages are that: (a) usually no *unique* analysis is possible; (b) where alternatives exist, the choice of the "best" analysis is somewhat arbitrary still; (c) the mathematics are difficult and uninterpretable by persons untrained in these concepts; and (d) the theory is still under development with the usual controversies over issues that frontier on the unexplored. Nevertheless, it may become a powerful tool for analyzing and systematizing diverse sociometric phenomena.[5]

RESISTING FORCES AND OTHER AUXILIARY CONCEPTS

A force as defined above is a net force, *i.e.*, that part of the stimulation which produces an acceleration of a social change in a population in addition to overcoming whatever resisting forces there may have been in the total situation. The problem of measuring these resisting forces, F_r, which resist the force, F, at issue (such as attitudes glorifying war which resist pacific propaganda) is one of developing indicia for the supposed resisting forces, measuring them, correlating them with the force at issue, and analyzing out of the vectors the positive, negative or neutral components which show the degree to which the hypothesis that F_r was resisting F is true or false.

A force should not be confused with a *cause.* Force is here defined, as in physics, in terms of effects "that which *has* accelerated a population." The nature of the partial causes of this measured effect, or total force, is a further problem in measurement or at least in forming hypothesis depending on the knowledge and insight of the investigator.

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[5] Full exposition of this vectorial analysis may be found in "The Vectors of the Mind," University of Chicago Press, 1935.

A *factor* denotes correlation with whatever variable it is a factor of; it may or may not be a cause.

An *agency* is the human and/or material organization which stimulates a group, *i.e.*, which generates a force, just as an engine does in physics.

Newton's Laws of Motion. The concepts may be further clarified in the form of a paraphrase in social terms of Newton's three laws of motion. Without asserting any metaphysical assumption about the nature of social phenomena, the paraphrases may be taken as a convention to define terms, a frame of reference, arbitrary perhaps, but useful as a standard to fix meanings of other concepts and units relative to that frame. The paraphrases are:

> (1) Whatever changes the status of a population or its process (or changing) in rate or direction, is called a social force.
>
> (2) Change of rate of a social change or process is proportional to the social force and takes place along the line defined by the indicia in which the social change is measured.
>
> (3) Forces and their total resistances are equal and opposite.

The first principle takes the existing static or dynamic state of a population as the zero point of a frame of reference and uses departures from it to define forces. Instead of the existing state any other could be taken, but how choose which of innumerable possible states of change to take as the standard? There is only one existing state at a particular moment, so that choosing it as origin of a frame of reference is logically compelling. There is no metaphysical assumption of inertia, *i.e.*, that the "normal" nature of society is to be in its present status or rate of change; it is merely a choice of coordinates which enables defining other concepts.

The second principle defines the units of force in terms of the units of the social change involved and points out their vectorial nature in having both amount and direction.

The third principle enables an equation of balancing all the positive and negative forces of a given kind, whether identifiable or not, that are acting on a population.

Finally, a warning as to some of the limitations of this system of concepts may prevent their misuse.

(1) These concepts should not be interpreted as implying a mechanistic conception of society; they are intended merely as definitions of some compound units for more precise expression of those few social phenomena in the very limited sector where basic units measuring social characteristics have been devised.

(2) The derived units are no better than the basic indicia; if these are inappropriate, inaccurate or inadequate for measuring the characteristic of which they are indices, the derived units will be bad ones in consequence. The essential problem is to get good indicia.

(3) In addition, the velocity, acceleration, force, etc., are in the nature of averages or trends for the periods specified. They oversimplify the situation wherever more detailed knowledge of variations is needed; they summarize net results obscuring analysis of component parts and neutralized resistances.

(4) The probable error formulae for interpreting the significance of observed quantities are based on the assumption of random sampling—an assumption which may not be tenable in a given set of measurements.

(5) The concept of indicia should not lead one to treat the diverse kinds all alike. It should lead to deeper study of statistics to learn the properties of each kind and the limits of their appropriate manipulation and interpretation.

THE SOYBEAN POINTS THE WAY TO AGRICULTURAL RECOVERY

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While in ancient Rome the ballots were usually cast by black or white beans, it seems very likely that in the present transitional stage of our country another bean, the soy, is destined to play a decisive rôle as an example of a constructive and practical way towards the restoration of the buying power to the American farmer—a *sine qua non* for the return of prosperity to the United States.

While agriculture's chief purpose merely consists in converting the unmarketable water, air and sunshine, as well as the minerals of the soil, into marketable products through the application of labor, tools and the use of various farm animals, it is evident that lasting agricultural prosperity is dependent upon further application of labor and machinery, namely, upon the development of industrial uses for farm products which would take care of the existing surpluses and create a continuous demand for agricultural raw materials.

The soybean is a vivid example of a crop with an amazing diversity of industrial uses. As yet, however, we are only beginning to suspect the extent of the potentialities which further scientific research may discover and which commercial development may transform into actualities.

The 20 per cent. of oil contained in soybeans was the main factor responsible for their becoming popular with the oil millers. In 1934 soybean oil constituted 11.6 per cent. of the world's production of vegetable oils. The United States production of soybean oil for the same year amounted to 1.6 per cent. of the total U. S. production of vegetable oils, constituting about 2.5 per cent. of our domestic cottonseed oil—a 2.5 times increase in the ratio soybean oil/cottonseed oil since 1930.

According to official figures, in 1935 American farmers planted 5,463,000 acres in soybeans grown alone. There was also a large acreage grown with corn and other crops for forage. The soybean crop in the six important bean-growing states—Ohio, Indiana, Illinois, Iowa, Missouri and North Carolina—is estimated at 33,541,000 bushels, nearly twice that of 1934 and three times the six-year average (1928–33).

The total quantity of domestic soybeans harvested in 1935 is placed at 39,637,000 bushels. Allowing 10,600,000 bushels of soybeans for seed, feed and other farm uses, over 29,000,000 bushels are available this season for crushing, export and carryover, compared with the 8,660,000 bushels crushed from the 1934 crop. Trade reports indicate that during the last part of 1935 soybean mills have been working at near capacity. Some cottonseed oil mills are also crushing soybeans in considerable volume, turning out old process, hydraulic type oil meal.

The hydraulic press system possesses the disadvantages common to all discontinuous processes, mainly, the large labor requirements and losses of time in charging and discharging the presses. The Anderson expeller was developed to meet the need for oil-producing equipment, which is continuous in its operation. The expeller, once started, requires very little attention, one man being able to care for several machines.

The disadvantage of the expeller is a larger power requirement than the hydraulic press method. Soybean meal output this season may be considerably larger than the record production during the last year, which totaled 223,000 tons.

Where the oil milling is done by the hydraulic press or the expeller method the oil comprises only about one seventh of the weight of the beans, while the cake or meal comprises approximately six sevenths. The demand for soybean meal has been for years the limiting factor for the expansion and volume of activity of our domestic oil milling industry. This meal is being used almost exclusively for feeding live stock, competing with our cottonseed and flaxseed meal, the market price for which is a major basis for determining the price to be paid for the new soybean crop. The price at which beans of the 1935 crop have been contracted by the soybean oil mills was thus set at 75 cents per bushel, and trade reports indicate that soybean oil mills have been working since at near capacity.

Figures, compiled by the Illinois State Agricultural Experiment Station, show that for five years (1927–31) the average yield per acre of gathered soybeans amounted for the whole United States to only 13.8 bushels per acre, with Illinois leading at 16.2 bushels per acre and Iowa following with 15.9 bushels per acre. It means that in 1935 the soybean grower was receiving in Iowa only $12.00 gross income per acre, while the cost of growing soybeans was estimated (for 1933) by the Iowa State Agricultural Experiment Station as $16.56 per acre (labor being calculated at 20 cents per hour). Even at a yield of 20 bushels of soybeans per acre the gross income at 75 cents per bushel would amount to only $15.00. It is therefore evident that the 1935 crop year brought the soybean grower in the central states a net loss per acre of $4.56 (at a yield of 16 bushels per acre) or of $1.56 (at a yield of 20 bushels per acre), the loss being proportional to the number of acres under soybean cultivation. In a 1935 Iowa State College publication it is estimated that with a yield of 20 bushels per acre soybeans would have to be sold for about $1.10 a bushel to return the same profit as corn.

It is evident that in order to bring about an increase in the price for the millions of bushels of soybeans crushed as well as to create a demand for additional millions of bushels and to make soybean growing a paying proposition it is necessary to remove the major part of to-day's soybean oil meal from the highly competitive and crowded feed channel and to convert it into products of higher market value. Such a move would also have a favorable effect on the price for cottonseed and flaxseed meal, thus helping in the recovery of another agricultural commodity. It is understood that where the soybean oil milling is being carried out from local beans by smaller rural mills and the meal is consumed for feeding the farm stock of the local district, the disposal of the meal could take place through the feed channel, since in such an instance the costs of transportation and marketing would be greatly reduced, thus enabling the rural oil miller to sell the meal at a reduced price to the bean-grower either directly or through the local feed mixer.

The three main industrially valuable constituents of soybean press meal are: the protein, over 40 per cent; the Phosphatides (Lecithin and Cephalin), from 2 to 3 per cent.; and the oil, about 5 per cent.

The soybean protein ("Glycinin") resembles in its properties the casein of milk. It is liquefied by solutions of weak alkalies and is precipitated from solutions by acids, the isoelectric point being a pH of about 5.4. This property of soybean Glycinin can be used by the

Food Administration for the quantitative estimation of soybean flour or meal in sausages. Adequately processed, soybean meal is suitable for mixing up to 50 per cent. in all kind of sausages which can be sold at a substantially reduced price, thus helping the meat packers to expand the volume of meat consumption by reaching customers who would not have the means to buy pure meat sausage.

When hydrolysed by acids or enzymes, soybean protein is converted into soy sauce, which is used for bouillon extract preparations and has been for decades the base of Worcestershire sauce. Brewers have recently become interested in soybean protein for increasing body in beer.

Glycinin possesses the property to form water — insoluble "glycinates" (similar to the "caseinates" of milk) with the metals of alkaline earths as well as with aluminum and the heavy metals. When glycinin is treated with formaldehyde it is converted into a thermoplastic resin. Briefly, soybean protein is capable of taking the place of casein (which is much more expensive and is being imported to the U. S.) in a large number of industries, such as sizing for paper, glue (waterproof) and plastics, all of which are already in existence in our country. At the 1933–34 International Exposition in Chicago all exterior walls and sub-floors of the Hall of Science were constructed of plywood panels glued with soybean glue. To-day soybean meal is used by the Ford Motor Company for the manufacture of horn buttons, gear shift lever balls, light switch handles, distributor bases, distributor cover and window trim strips. When great resistance to moisture or high dielectric strength is desired, resins are produced by the simultaneous condensation of the soya proteins and phenol or urea with formaldehyde in the presence of cellulose and carbohydrates. With the completion of the new $5,000,000 River Rouge plant for soybean plastics, the use of soybean meal will extend to making dashboards and probably also automobile bodies.

As early as 1915 a United States Patent was granted to Dodd for making plastic materials from soybean meal, followed in 1917 and 1918 by a whole series of patents issued to Satow. To-day their term has expired and the road is open to ambitious manufacturers to use soybean meal for the manufacture of soybean protein itself (called incorrectly "casein"), of plastic materials from the protein, wall board, floor cover compositions, insulating compounds, artificial leather, etc.

In recent times a method has been devised for hardening and strengthening iron and steel by exposing the heated metal to a composition containing 90 per cent. of soybean meal mixed with various salts. It is claimed that this method of hardening requires only one tenth of the time required for the same purpose by the usual methods.

Soybean meal has attracted much attention as a base for water paint (in combination with caustic lime) which is being recommended for farm buildings, fences, garages, advertising boards, depots, etc. It would make an excellent whitewash material for painting the middle line of our highways, its guard fences, marks, danger signs, etc., due to its cheapness and water resistance.

Soybean meal could find a large outlet in the building of our roads, since it is an emulsifier for asphalt and coal tar. It has also been recommended, in combination with alkalies, as an emulsifier for mineral oils for dormant spray purposes, for copper spray mixtures (Bordeaux), etc. Soybean meal is a valuable protective colloidal mixture and an adhesive as well as an emulsifying agent. The latter property is due largely to the presence in soybean meal of a comparatively large percentage of phosphatides of the lecithin type (cephalin's emulsifying properties are not sufficiently known).

In a general way lecithin seems to act on fats as a protective colloid, and it tends to prevent the separation of fractional constituents. When cooled, liquefied fats containing lecithin solidify to a homogeneous mass. One million pounds of commercial soya phosphatides are used annually in the margarine industry of Germany, and the other applications of lecithin include the baking and confectionery trades and the textile industry. Being an excellent emulsifier and possessing a high fat-liquoring value, soya lecithin is particularly valuable for the leather industry, causing an increase in the absorption of grease by the leather and permitting the use of higher temperatures. Soya lecithin is also an excellent leather softener and penetrates the hide and becomes partly fixed in it and can not be later washed out as easily as the sulfonated oils. Recently the rubber industry has begun to use soybean lecithin for milling rubber to powder as well as for certain rubber compositions.

Soya phosphatides (lecithin as well as cephalin) are shown to possess antioxidant properties, and in amounts of from 0.05 to 0.1 per cent. are capable of "protecting" edible fats and oils from rancidity.

While the emulsifying properties of lecithin are well established, those of cephalin are not, and it is desirable to change the existing commercial habit to label as "lecithin" mixed soya phosphatides which consist *de facto* of only about 40 per cent. of lecithin and 60 per cent. of cephalin. Cephalin, under its own name, has every chance of becoming a commercial success in its field, while at present it is in many instances a liability.

Up to recent times commercial soya phosphatides have been imported to this country from Germany and Denmark, and during the depression years of 1930–33 its sales showed a steady gain. At present some domestic soya "lecithin" has appeared on the market. It took our industries ten years to establish the first working soya phosphatides extraction plant since the first U. S. patent on soya lecithin extraction and purification has been granted to Bollmann in 1923. While hen's eggs and the soybean oil meal contain approximately equal amounts of phosphatides, the market price for the latter is from ten to twenty times cheaper than for egg lecithin, thus opening a much wider range of possible commercial applications. At the existing market price (about 50 cents per pound of the technical grade soya phosphatides containing 40 per cent. of oil vehicle) an additional income of about 50 cents per bushel of soybeans (as well as from the meal derived therefrom) is assured to the progressive manufacturer. It is surprising to notice that in the 1930 official booklet on soybean oil meal, issued by our National Soybean Oil Manufacturers Association, soya phosphatides are not even mentioned among the components of the meal.

The phosphatides can be separated from the soybean (as well as from the oil meal) only by the extraction (solvent) method, and the developing of soybean extraction is one of the major problems which is confronting our soybean industry. Against our yearly volume of 5 million bushels of crushed beans Germany used in 1931 a volume of 37 million bushels and in 1932 as much as 44 million bushels, all soybeans being imported from abroad and handled by the solvent process which separates the three main commercially valuable constituents of the soybean, the protein meal (flour), the phosphatides and the oil. Extracted soya meal has a number of industrial applications for which press meal (still containing 5 per cent. of oil) can not be used.

In our country extraction is only in its infancy, because of the absence, up to recent times, of a low-priced dependable continuous extraction unit simple and safe to handle, as well as to the lack of printed information dealing with solvent extraction, the organic solvents (hydrocarbons and chlorinated hydrocarbons) and their safe handling, the further procedures in separating and refining the phosphatides and the commercial outlets for soybean extraction materials. Very few U. S. patents are dealing with these problems, and they are to-day an open and promising field for the research worker and the industrialist alike.

By the extraction method less oil is left in the meal to be sold at the meal price of 2 cents per pound instead of the oil price, 9.25 cents per pound. This difference on a twenty bushels per acre yield of beans, containing 18 per cent. oil, amounts to $2.27 per acre on a ten-ton per day plant, or $11,350 per year.

In 1934 our domestic soybean oil has been absorbed by the following trades:

Compounds and vegetable shortenings	2,735,000	pounds
Oleomargarine	24,000	"
Other edible products	509,000	"
Soap	1,354,000	"
Paint and varnish	10,451,000	"
Linoleum and oilcloth	2,843,000	"
Printing ink	59,000	"
Miscellaneous products	2,109,000	"

To-day the edible oil outlet is consuming 90 per cent. of the total domestic soybean oil produced, due to the advantage over other oils in rancidity resistance, better color and satisfactory price. It is regrettable that the industries using soya oil for margarine, salad oil and mayonnaise never make mention of soya oil as a constituent of their products.

The press — expeller — and solvent-extraction soya oil, when refined, is equally good for use in the paint industry. Expeller oil contains traces of phosphatides and solvent-extracted soya oil is rich in these constituents which, unless removed, act as retarders of oxidation.

About twenty years ago, H. A. Gardner, the present director of the Institute of Paint and Varnish Research, demonstrated that through heat treatment and the use of proper dryers raw soybean oil may be dried almost as rapidly as boiled linseed oil. The drier combination that produced the best results were a mixture of manganese linoleate (0.03 per cent. Mn), cobalt linoleate (0.01 per cent. Co), and lead linoleate (0.20 per cent. Pb).

The valuable natural properties, elasticity and flexibility of film and non-yellowing, are best utilized when soybean oil is polymerized. Soybean oil has also been recommended for grinding paste colors. To-day, in the state of Illinois one out of every ten farmers has one or more buildings painted with a paint containing up to 33 per cent. of soybean oil in the vehicle. This has been achieved through good quality soybean oil paint and a reasonable price, through the cooperation of the State Agricultural Experiment Station and the example of the state administration who painted with soybean oil paint the state building at the Chicago Fair as well as the governor's executive mansion.

In 1934 the soybean used in our paint trade was only 2.8 per cent. of the total amount used in that industry. Further development and expansion along this line seems desirable, since present annual importations of flaxseed are amounting to about 500 million pounds, which corresponds to about 150 million pounds of linseed oil (37 per cent. of the total production). Linseed oil and soybean oil are quoted to-day on our market about at par, while in the past soybean oil was always quoted a few points below linseed oil. Considering that excise taxes on imported oils are rapidly rising, the domestic paint industry will directly benefit by developing a domestic source of supply for its raw materials.

Soybean oil has found an application as a core sand dry bond, and its possibilities as a basis for "cutting oil" are being studied at the University of Michigan Engineering School, both fields being to-day dominated by linseed oil.

At present soybean oil and its acids, as well as glycerine, are used fairly extensively in a number of alkyd resins which are sold under various trade names, such as Glyptal, Rezyl, Dulux, Beckosol, etc. The Glyptal type synthetic resins are used by practically all varnish factories and to a large extent by the lacquer industry. One distinct advantage of these resins is their durability, their aid in retention of tint values and high gloss.

In high-temperature bake enamels the gloss, durability, adhesion and flexibility of enamels made with soybean oil in conjunction with synthetic resins of the all-phenolic type has led to tremendous increase in the use of soya oil. The oil has the advantage of being much cheaper and more readily available from domestic sources than tung oil. High-bake enamels of this kind open up new fields of use for the varnish manufacturer. They have the elasticity and toughness which is desired in a lacquer film and at the same time have water-resistance and alkali-resistance which can not be obtained with ordinary lacquer or quick-drying enamel. The flexibility of these films also opens the possibility of producing more suitable wire enamels which do not soften so readily under heat, and which when wound under tension, will not cause short circuiting due to the softening of the varnish film

Our automobile industry is to-day using large quantities of synthetic resins and enamels where soybean oil is one of the constituents. A finish for automobile bodies was developed by the Ford Motor Company, employing soybean resin as a coating and soybean oil as a carrier of pigment.

The value of soybean oil for the synthetic resin and high-temperature bake-enamel development was largely due to the fact that this oil contains about 50 per cent. of linoleic acid. The presence of this acid makes soybean oil well adapted also for the manufacture of linoleum as well as soft soap where linseed oil is at present still a major ingredient. Soaps (hard as well as soft), containing soybean oil, are known to withstand hard water very well without impairment of their lathering capacity which view is contrary to the much advertised statement that coconut oil or palm kernel oil are absolutely essential in soap which is employed in waters having any degree of hardness. For this reason soap manufacturers could use soybean oil to a much larger extent than they do to-day, and it should be remembered that in 1917 over 124 million pounds of soybean oil have passed through the kettles of our soap industry for hard and soft soap alike (some of it after being hydrogenated). During the post-war period our automobile variety of soft soap depended largely upon soybean oil. If the Guffey-Dockweiler Bill, permitting duty-free imports of coconut oil to the United States for soap-making, is passed, it will substantially damage the cause of our soybean grower. While the price for an oil or fat is undoubtedly an important factor where a large percentage of the material is used, it is still advantageous and profitable to incorporate a smaller percentage of a more expensive oil when the quality of the soap is substantially improved by it.

Some years ago soybean oil was converted into an effective and comparatively cheap waterproofing substance. It is a viscous yellow liquid which is mixable with cement and does not affect its strength. It stands sea water exceedingly well. Its uses are numerous—for foundation work, basements, roof gardens, tunnels, bridge piers, reservoirs, cement pipes, etc. It prevents effectively the corrosion of steel skeletons in reinforced concrete.

In reviewing the industrial uses of the soybean the food angle should not be overlooked. During the last decade edible whole flour is steadily gaining in popularity. With the beany taste removed by distillation and the keeping quality enhanced, a high concentrated and palatable product is available which in quantity and quality of protein, as well as in fat, possesses double the value of lean beef, and which in addition contains over 2 per cent. of phosphatides, nearly all the known vitamins and an ash of high alkalinity, while containing neither starch nor gluten. In amounts of 20 per cent. of the mix, whole soya flour is an ideal supplement to wheat for bread and macaroni products, and could be responsible for the shifting of wheat products from the class of energy-producing foods to a level of full-value foods. Soya flour is the miller's best friend and may help wheat to recover some of the 20 per cent. decrease in wheat consumption which took place in our country during the twentieth century as a result of the substitution of machinery for manual labor as well as the advent of the automobile.

It seems evident that to-day the soybean is one of the most promising agricultural plants for an almost unlimited variety of industrial uses, most of them non-competing with existing domestic products, and as such offers the broadest outlook for making farming a paying proposition. The cultivation of soybeans as a cash crop has every chance to expand far beyond the existing commercial level, which will no doubt create numerous new industries and by this do its share in relieving unemployment. The soybean thus seems to point towards a practical and constructive way for many a crop which, through the lasting efforts of all concerned, may lead to the ultimate well-being of the farmer, the workman and the business man alike.

THE EFFECT OF CRUDE OIL POLLUTION ON OYSTERS IN LOUISIANA WATERS

By Drs. PAUL S. GALTSOFF, HERBERT F. PRYTHERCH,
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THE mortality of oysters in Louisiana waters in 1932–33, coincident with the development of oil wells in the coastal areas of the state, brought up again a question as to the possible effect of oil on oysters and marine life. The writers set out to investigate exactly what bearing oil well pollution might have on oysters; to this end funds were allotted in 1934 by the Civil Works Administration, which sufficed to carry out a hydrographic survey of the conditions in Terrebonne and Timbalier Bays, La., and laboratory experiments at Beaufort, N. C., Woods Hole, Mass., and Washington, D. C. As a result of this work much has been learned about the possible effect of oil pollution on oysters and the conditions in the Louisiana oyster beds. The report comprising the results of the investigations has been completed and will be published by the Bureau of Fisheries in a short time.

The questions confronting the investigators were two—whether the unusual mortality which occurred in Louisiana in 1932–33 was attributable to the discharge of oil and bleed water, and how further development of the oil resources of the coastal section would affect the cultivation of oysters.

An important difficulty in answering such questions is that the marine biologist is called in to investigate the cause or causes of mortality several weeks or months after death has occurred and when the conditions responsible may have been changed or removed. The present report fails to give a definite answer to the cause of the heavy mortality of 1932–33 in Louisiana, but does throw some light on an even more important matter, namely, the possible dangers of oil pollution to oysters. Because of the limitation of funds, the authors concentrated their attention on experimental studies of the effects of oil on the behavior of oysters and the growth of diatoms which constitute the principal part of the oyster diet.

Preliminary investigations, carried out by Prytherch in 1933, failed to reveal the existence of a direct correlation between the intensity of mortality and the distance between the affected oil bottoms and oil wells. A number of oysters, barnacles and green algae were found growing on the piling of oil wells, and no unusual mortality was observed among other organisms. The presence of small numbers of oysters on piling of oil wells was also observed in 1934 by Galtsoff and Smith. Examination of oysters and plankton showed that apparently there was no interference with the development of gonads, spawning and setting of the larvae. The diseased condition of oysters was evidenced, however, by the loss of muscular tonus and the failure of the adductor muscle to maintain closure of the shell. It is known that if such a condition continues for a long time it results in a stunted growth and abnormal shape of the shell. No unusual changes in the salinity of water and other hydrographic conditions, which might account for a great mortality, were disclosed by these observations.

The oyster enemies, the borer, the boring clam and the boring sponge, are rather abundant in Louisiana waters. Many dead oysters examined in 1933 showed heavy perforations caused by the boring clam and sponge, but, on the other hand, in one place which was examined, 95 per cent. of dead shells were not infested by these pests. Oyster growers have not noticed an unusual increase in abundance of oyster enemies, and no evidence has been obtained which would indicate that such an outburst occurred at the time of the mortality in the winter of 1932–33. It is significant that in 1933 the mortality affected chiefly the larger and older oysters of marketable size and in several instances was especially severe among the recently transplanted oysters. Undoubtedly, the practice of overcrowding the beds by planting from 700 to 900 barrels of oysters per acre may be one of the contributing factors which aggravates the situation and, in case of adverse environmental conditions or the poor condition of the oysters, may materially increase their mortality.

A more detailed survey of the oyster bottoms, made by R. O. Smith in 1934, failed to assign the mortality to any known disturbance of the natural conditions on oyster beds, as, for instance, temperature, salinity, current and invasion of enemies. It has been noticed that, in general, mortality has been higher on soft, muddy bottoms than on hard ground. At the time this survey was carried on, pollution was noticeable at the mouth of Bayou Grey, where the surface of the water was covered with oil for a distance of three miles below the wells and there was some mortality on the oyster beds of this section. All shells were covered with a brownish black coating of tarry consistency and the meats were unpalatable because of the strong oily flavor. Considerable quantities of oil were held by mud, and oily patches appeared on the surface when the bottom was stirred. Light films of oil were observed also in the vicinity of the Lake Barre wells. In 1934 oysters on many beds throughout the region did not become fat until February or March, which points to a possible scarcity of food or to a disturbance in the functioning of the organs of feeding.

The shallowness of the water throughout the oyster-producing region in Louisiana must be regarded as a factor which tends to magnify the action of any polluting substance. Due to stirring by wind the water carries much suspended matter which may absorb the pollutant, transport it over wide areas and deposit it on the bottoms far from the source of pollution. Observations in the polluted areas show that on account of the absorption by suspended clay particles, oil quickly disappears from the surface and, after being deposited on the bottom, remains there for a long time.

No information was obtained by the two surveys upon which to base an opinion as to the direct cause of mortality, but ample experimental evidence has been accumulated to show that the presence of crude oil in water produces conditions inimical to oysters.

The first series of experiments, designed to determine whether oysters could be killed by the presence of oil in the water or by direct contact with oil, gave negative results. Unfortunately, because of the circumstances over which the investigators had no control, these experiments were carried out not in Louisiana, but in a different environment at Beaufort, and uncultivated oysters taken from local oyster reefs were used. Samples of crude oil collected by the State Conservation Department from Louisiana oil wells were shipped to Beaufort and used throughout the experiments. It is quite possible that the results might have been different had Louisiana oysters been used. In a series of experiments, lasting from two to three months, the mortality of oysters kept in running sea water under a surface layer of oil and those kept in sea water that passed through oil was no greater than that in the controls.

In another set of laboratory experiments no higher mortality than that in controls was observed among the oysters which, over a period of 6 to 8 weeks, were immersed at regular intervals in oil. In some of the experiments the mortality among the controls was as high as 50 per cent, indicating unfavorable laboratory conditions under which the animals were kept. It is possible that these conditions beclouded the effect of oil on oysters.

The fact that oysters survived the treatment with oil does not indicate that they were not affected by it. Analyses made by Galtsoff show a slight decrease in glycogen content of oysters kept in the laboratory in the oil-polluted water. The result may be due either to the disturbance in the functioning of the feeding apparatus of the organism or to the decreased supply of food.

A regular operation of the muscular mechanism involved in closing and opening of the shell is prerequisite to the normal feeding of the oyster. Two sets of experiments carried out by Prytherch in 1933 and Galtsoff and Smith in 1934, gave identical results, showing that the presence of oil has no effect on the mechanism of the adductor muscle.

In the first set of experiments, continuous kymograph records were obtained of five oysters, which were kept under observation for three months. The average number of hours per day the oysters were open was 11.2 for the controls and varied between 10.0 and 13.6 for the experimental oysters. In the second set of experiments, six control oysters, kept under observation from four to fourteen days, were open on the average of 10.5 hours daily, whereas the average figure for ten experimental oysters, kept under observation from four to eight days, was 9.6 hours. In both cases the difference is insignificant.

Although the presence of oil in the sea water does not reduce the number of hours the oyster keeps its shell open, and therefore the duration of feeding of the mollusk is not decreased, the rate of feeding is early affected by the presence of polluting substance. As the feeding of the oyster is primarily dependent upon the amount of water passed through the gills, the rate of pumping of water can be used as a measure of the rate of feeding. The results of the experiments show that crude oil contains substances soluble in the sea water which produce anesthetic effects on the ciliated epithelium of the gills. The inhibiting action is not due to the mineral salts that may be leached out in preparing the water-soluble fraction of the sample of oil by shaking it with sea water. It is apparent that certain organic compounds of oil are slightly soluble in sea water. This conclusion can be drawn from the observations that after twenty-eight washings with water, the sample of oil did not lose its toxic property and yielded an extract, the anesthetic potency of which was equal to those obtained with the first washings. The inhibiting effect of the water-soluble fraction is proportional to its concentration. From a large number of experiments the inference can be drawn that a concentration between 20 and 30 per cent. of the soluble fraction will, on the average, reduce the rate of feeding of the oyster to one half of its normal value.

Under the conditions of the experiments, the recovery of the ciliary motion following the removal of the oil extract was almost complete. Inasmuch as the experimental oysters were kept in the extract only for a limited period of time, the result of the prolonged exposure remains to be determined. There was no indication in the present experiments of an increased tolerance in oysters due to repeated treatment.

There was a large variation in the percentage of depression caused by a given concentration of the soluble fraction on individual oysters. Two explanations suggest themselves. First, there is a possibility that in spite of the precautions taken in preparing the soluble fraction, the toxicities of individual samples were different. Second, the oysters used in the experiments may have different sensitivity and tolerance. The second explanation seems to be more plausible, for the wild oysters used in the experiments at Beaufort, coming from exposed flats, greatly varied in appearance, glycogen content and other characteristics.

From a large number of experiments with the water-soluble fraction the inference seems to be inevitable that crude oil discharged in the sea, regardless of whether it floats on the surface or, having been absorbed by mud particles and deposited on the bottom, continuously yields water-soluble substances which narcotize the ciliated epithelium of the gills, reducing the rate of pumping of water and therefore materially decreasing the amount of food obtained by the organism. This should lead to gradual starvation and weakening of the organism. The chemical nature of the substances and their concentration in the oil-polluted areas remains to be determined by future investigations.

The effect of brine or so-called "bleed water," which accompanies oil discharged by the wells and is usually dumped into the sea, has been studied by using the same technique as was employed in the experiments with oil. It has been found that bleed waters of Lake Barre and Lake Pelto do not affect the muscular mechanism of the oyster in relatively high concentrations, provided the quantity present does not increase the salinity beyond the limits of tolerance. A 10 per cent. concentration of bleed water may exert a stimulating effect on the ciliated epithelium, at least in some of the individuals. The depressing effect occurs at the concentration of 20 per cent. and higher. A 33 per cent. solution reduces the rate of pumping of water by the gills to 32.6 per cent. of its normal rate. The percentages of brine which cause this or greater depression are beyond any possibility of occurrence in nature.

Experiments were set up to throw light on the possible effect of oil and bleed water on the production of the food of the oyster. It has been assumed that the results of the laboratory experiments with the diatom, Nitzschia, which occurs in the normal habitat of the oyster, and constitutes an important element in its diet are applicable to other species of diatoms. It has been found that the presence of a heavy layer of oil on the surface of culture flasks inhibits the growth of Nitzschia when oil remains on the surface for a week or longer. The soluble fraction of oil exerts a retarding effect on the growth of Nitzschia in concentrations of 25 per cent. and higher and when the extract is permitted to act over a considerable period of time. Low concentrations may have a slight stimulating effect. In many instances the addition of the oil extract stimulated the growth of bacteria, small numbers of which were always present in cultures, and caused the death of diatoms.

Water-soluble substances, obtained by dialysis through a collodion membrane, also exerted a retarding effect on Nitzschia, both in natural sea water and in Miquel solution.

Bleed water retards the growth of Nitzschia, the inhibiting effect being pronounced in concentrations of 10 per cent. and higher. The retardation of growth is directly proportional to the concentration.

The experimental evidence presented in the report shows that the discharge of oil into the sea produces profound changes in the normal environment of the oyster. The substances which gradually dissolve from oil in the sea water irritate the delicate ciliated mechanism. In a very dilute solution they may act as stimulants, but in higher concentrations they inhibit the activities of the ciliated epithelium and may bring about complete stoppage of the current of water through the gills. The same substances which reduce the rate of feeding of the organism affect its food supply by retarding the rate of propagation of diatoms. Obviously the presence of oil creates adverse conditions.

In the light of the present investigation, it is easy to conceive that, when the constitution of the organism is weakened by unfavorable meteorological conditions, natural changes in the environment or attacks of enemies, the pollution of water with oil may become a deciding factor which may cause irreparable injury, resulting in death. It is obvious that from the point of view of conservation, the natural resources of the sea must be protected from this danger.

PROTECTING CHILDREN FROM DEPRESSION DISTURBANCES

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Six million children are already scarred in the economic struggle. The newborns are feeble; the infants are still strong; the children are stunted; the adolescents more sophisticated. An appraisement of under-privileged children reveals retrograde growth and development, resourceless emotional and social precocity, unadjusted personalities. The greater the toll of unhappy children the greater the incongruity of the coming generation. America's young men and women of to-morrow will thus become as ravid as those of Europe to-day—restless, rebellious, revolutionary. Physical deprivation at one age leads to mental distortion at another; the one is irreparable, the other insolvent.

What are the beginnings of child decadence in this country have reached extreme proportions in Europe. There it started slowly but cumulatively at the onset of the war when children were provided with inadequate food, little medical care and less security. But the actual deprivation that children suffered was no more deleterious than the indirect effects of world war activities. For example, the wild exportation of dairy products from Denmark deprived children of vitamin A, blinding hundreds with the disease xerophthalmia. The dearth of milk in Belgium and Germany deformed thousands with severe rickets. Lack of wheat gave them beriberi; the stinting of meat anemia. And the food rations for children in Central Europe produced such degrees of undernutrition that led to wide-spread childhood tuberculosis.

The by-products of these ailments were destructive of the personalities of Europe's children. It took long for the effects of these hardships to be recorded in their physical and mental conditions. The deformities diminished physical efficiency, curbed maturation, weakened personalities. Infections permeated the vital tissues, distorted their functions, sapped their stamina. Insecurity stifled emotions, strained nerves and unbalanced minds. The Europe of to-day thus reflects deprivation with cumulative mental and physical ill-being. What has happened in lands of economic difficulty is not inevitable in this country. The *modus operandi* of human beings is alike throughout the world, although the course may appear different. Because America is in its material ascendancy the effects of the depression are less blatant.

The birth rate has shown its characteristic increase during troublesome years. Births are prolific among the poor and even more so among the "depression poor." Certainly an increase in the size of a destitute family is no stimulus for the head of the household to become a more competent provider. A generation ago large families dwindled to a meager few grown-ups after disease and pestilence destroyed much of their progeny. Such does not maintain to-day, for the chances of survival are all with the young, provided they are properly maintained and medically supervised. The burden of the underprivileged large family becomes that of the state and nation. Apparently that stratum of society which can well afford to maintain large families controls conception. Even churches of many denominations advocate certain methods for regulating the size of families and present the information to those in quest thereof. But the parents who are most in need of this knowledge rarely seek it. A worthy service on the part of governmental agencies would be to inform members of large underprivileged families ways of maintaining them without undue propagation.

The newborns of the "depression poor" are more feeble than their former progeny. The weights are less, although the lengths tend to be the same. The babies are less vigorous, although physically they appear well built. They develop more disturbances incident to the initial adjustment. The reaction of newborns to the conditions of their new environment is an index of the vitality acquired in utero. Those too feeble to cope with the situation after birth succumb promptly because they have probably been exhaustion products. There is a popular misconception that these neonatal deaths are due to developmental anomalies. As a matter of fact only 2 per cent. of newborns lost at birth are the result of congenital malformations. Two thirds of the deaths are the result of disturbances associated with the nature of the delivery and the other third are the consequence of infections acquired before, during or after delivery. Obstetrical technique is being perfected in spite of depression, but even superior medical care of newborns can not save lives of enfeebled stock. The only means of diminishing the loss of the newborn population is to provide for their supervision prenatally. Mere provision of emergency care during the preconfinement period is a hazard to both mother and offspring. The character of the delivery is determined by the supervised course of the entire period of pregnancy. Therein lies the key to most of the preventable maternal difficulties and deaths. The greatest disturbances befall the child long before it is born. Many of these are preventable by proper medical care of the expectant mother from the first weeks of pregnancy. The provision of more health stations, obstetrical clinics and maternity centers to coordinate their supervision with the economic status of the family will improve and protect the progeny.

Infants have suffered least from the effects of the depression. Feeding has become so simple and the care so standard that babies thrived in spite of adverse home conditions. Nevertheless, a comparison of infants from various sectors of society shows less favorable body build for the underprivileged than for the well-to-do. Indeed, the difference in the vitality between these two groups is sufficiently great to take heed. It suggests that the factors responsible for the superior rearing of infants are worthy not only of maintenance but of enhancement. Governmental agencies should therefore provide more health stations, well baby clinics, health centers in the districts that have suffered most from economic stress. There are apparently enough agencies qualified in infant welfare, enough public health nurses at hand and enough physicians without personal practice to serve in this cause. All are available and yet have not been marshalled for the infant population. The cost of such centers is less of an item than the political resistance to community health organizations. The greatest conflict is between private practice and so-called socialized medicine. Provision of infant welfare stations is an extension of a service well under way and does not conflict materially with desirable private practice of physicians.

School children have suffered tangibly from the depression. Growth and development have been definitely diminished compared with their previous tempo of progress. Contrasting are the physical demarcations in the children of the well-to-do, the "new poor" and the chronic poor families. The children of the first group are accelerated two to three years, while those of the other two groups are manifestly retarded. The children of those families who were hardest hit by the depression suffered most physically. The young apparently reflect in ill health any sudden change in lowering their standards of living.

The first manifestations of deprivation constitute malnutrition. It represents varied symptoms and physical signs peculiar to each child. Many are the possible disturbances consequent upon malnutrition, for at least forty nutrients are necessary for daily maintenance and growth. If any one of these are inadequate or deficient, nutritional deficiencies develop progressively. The deprivation becomes cumulative and the children really suffer from an aggregate of several deficiency diseases. Not only is growth affected but the physical efficiency of all tissues impaired. Most malnourished children are maintained on essentially carbohydrate feedings of limited food value. Their energy requirement is usually fulfilled by an abundance of rice, macaroni and beans with consequent protein, mineral and vitamin starvation. The undernourished young bodies are media par excellence for the dissemination of infection. And unhygienic overcrowded quarters, housing families that are doubling up in homes, become veritable incubators of infections and cross-infection. They gradually devitalize malnourished children, retard their development and blight their youth.

Contrary to current notion growth does not cease during semi-starvation. Certain tissues appear able to appropriate nutrients and grow at the expense of other organs of the body. There is such a harmonious equilibrium between tissues that none wanes without the others responding to their cause. Most of the required nutrients of the body are distributed in depots ready for release on tissue demand. The body begins to live from its inner self rather than from the external environment. These self-consuming mechanisms have their limitations. The usual change in body build during periods of undernutrition is abnormal elongation. Persistent skeletal growth results in emaciation caused by atrophy of the softer tissues. In some children there is also an enlargement of the head and a disproportion in the growth of the extremities, depending upon the age and type of malnutrition. Distorted growth is more prevalent during the cycles of rapid growth—infancy, the period of second dentition and pubescence. During the interim periods of body broadening there is less disproportion in body build from malnutrition.

What is the possibility of recovery from prolonged malnutrition? The child's body is a very labile mechanism with remarkable powers of recovery, provided proper nutrition is afforded before extreme stages of malnutrition are reached. The younger the child the less complete the recovery because of accelerated growth during the first years of life. Infants who lose more than 30 per cent. of their weight have their tissues so inalterably affected in structure and function that they usually succumb. Older children have greater powers of resisting such tissue changes. In the Russian famine children recovered from extreme emaciation but were markedly thwarted in body build and in physical functioning. No generalizations are possible with regard to the amount and degree of dwarfing from undernutrition because of the many factors involved in growth.

Whatever the cause of malnutrition, it is ever an index of extreme maladjustment, physical, nutritional or emotional. The lean child does not necessarily exemplify undernutrition because average body measurements do not indicate nutritional status. The malnourished child fails to gain in weight, has flabby musculature, strained nerves, poor digestion, lowered resistance. The condition is alleviated by a body-building dietary to effect healthy gains in weight. It is not sufficient to overload the body with fat-forming foods. All forty nutrients are indispensable for well-being. The diet should furnish the largest number of tolerated calories in their most digestible forms. Diversification of food is not necessary, for no disturbances are ever caused by monotony of diet.

Food money for the underprivileged should be distributed in fifths—one fifth for milk and its products, one fifth for vegetables and fruits, one fifth for meat, fish and fowl, one fifth for breads, cereals and starchy foods and one fifth for the foods particularly cherished by the family. At least one pint of milk, fresh, evaporated or dried, is necessary for a child. Each form of milk provides the same content of nutrients. The choice should therefore depend on the cost. Similarly, the cost of vegetables and fruits is no indication of their nutrient value. The soil is not in league with man's palate. The less expensive produce furnishes the necessary minerals and vitamins, in tomatoes, potatoes, cabbage, yellow turnips, bananas, prunes, obtained raw, preserved or canned. Every housewife knows that the less preferred cuts of meat are least expensive. Some of the viscera are equivalent to liver in superior protein and anti-anemic factor. Such organs as lung, kidney, spleen and tripe are economical because of infrequent demand. Whole-grain breads and cereals are preferable and may be obtained at half cost when bought one day old. The nutritional value is the same and the digestive greater for children. Cod liver oil is a necessity for undernourished children. The highly advertised brands are biologically tested but expensive. Other fish oils are equally effective and more economical.

Relief for the depression poor maintains adults at the expense of children. Few parents, irrespective of intelligence, appreciate the food requirements for their children. And emergency feeding is given no consideration in the strain of family insecurity. No attempts have been made by governmental bureaus to allocate foods of choice for children. Certainly the disbursement of relief funds requires nutritional supervision of malnourished children. The dead hand still guides many an archaic organization impervious to progress. They take no precautions to safeguard the well-being of youth in distress. It may be well for the grown-ups gripped by baseless food prejudices to continue in their dietary abnormalities. Their habits are difficult to change. And those who make intelligent efforts to readapt themselves to newer knowledge merely rearrange their prejudices without actually changing their habits. The damage done to children under such primitive home surroundings is irreparable. There is an administrative and educational challenge to the relief organizations at work to spare children from dietary prejudices and help build for them sounder physiques. Malnourished children require nutritional supervision at home and medical supervision at special clinics. Food deficiency alone is rarely the factor productive of extreme malnutrition. Medical care must be provided to eliminate focal infections, correct physical defects and regulate health habits apart from perfunctory arrangement of adequate dietaries.

Physical degradation of children has been associated with deep-seated disturbances. Intangible and devastating indirect effects of the depression are emotional and mental illness. They are the devastating consequences of family integration. The problems of the grown-ups become the anxieties of the young. Family relationships mould the personality traits and life attitudes of children only to distort them under economic stress. The home atmosphere is tense with concern about the family income. The children worry about diminished comfort, change of residence, loss of friends, lack of clothes, insufficient food, deprivation of delicacies. These are but few of the daytime difficulties that befall the child at home. Equally prevalent are the night problems. The crowding of several members of the family in the same room if not the same bed instills emotional immaturity, protracted dependence, irritability, masturbation. Thwarted physically and emotionally, the child's attitude towards life becomes distorted. He is rebellious, disagreeable and sullen. The nervousness is expressed in fears, physical complaints and anti-social activities.

The ever-present sense of insecurity troubles children of the new poor more than those of the chronic poor. The sudden change in the economic status of the family disequilibrates sensitive personalities, with consequent functional disorders. Mere physical examination reveals no organic disease. Physicians confronted with no physical basis for complaints shrug their shoulders with a feeling of despair with regard to alleviating such intangible disturbances. The province is in the realm of the child psychiatrist who has determined the relation between the psychogenic factors and physical dysfunctioning. The child makes an unconscious flight into disease from which he derives emotional gain. Expressed differently, home problems precipitate a body protest in the child. The physical disorder serves as an outlet for worry, disappointment and other difficulties. Few realize that a child takes his troubles as seriously as adults take theirs. The mental makeup of the child also has a psycho-pathology of its own. It is unraveled, not in terms of the irrelevant symptoms presented but rather in terms of the child in his entirety with attention to his constitutional, physical, mental, emotional and environmental peculiarities.

The more serious evidences of maladjustment are shyness, sensitiveness, lack of sociability, suspiciousness, resentfulness, fearfulness, cruelty and tendency to depression. Parents erroneously consider other types of negative behavior such as cheating, lying and stealing as more serious. Misbehavior calls for prompt interpretation of the child's difficulties. It is necessary to seek the motif underlying the behavior rather than to label it good or bad. The first approach in abating personality difficulties is to work with the child as much as possible. Physical deviations should be corrected to set up a level of well-being that is more desirable for successful adjustment, for behavior constitutes a set of overt functions so integrated in the total personality that smooth working depends upon positive health. Then comes the correction of faulty attitudes which the child has formed with regard to his psychic disturbances in the depressed environment. Parents frequently use the term nervousness as an explanation of behavior difficulties. The term they consider harmless sets up strange ideas in the child interfering with simple appeal to his powers of reason. Once self-confidence is instilled the child will overcome his difficulty to the extent that he gradually becomes adjusted to the exactions of his environment.

But abnormal behavior is the consequence of strained inter-personal relationships. As it is ineffective to treat a complaint without considering it an integral part of the entire being, so is it impossible to deal with the child detached from his environment. The whole family is intimately linked with the child's difficulties. Their over-indulgence, over-ambition or indifference and carelessness breed behavior disorders. The child's educators must be educated by enlisting their cooperation intelligently, convincingly and concretely. Improvement is possible only with a modification of the environmental circumstances that have precipitated the strain and simultaneously effect a change in the parent's attitude towards the child. Underprivileged parents and children bear three kinds of trouble—those they had, those they have at present and those they expect to have. Even if all the material difficulties were adjusted to their immediate satisfaction the adults would still be brooding and the children would be in accord. It is therefore equally important in providing relief to teach parents to view life's ups and downs with equanimity, to try to maintain a calmer outlook on life if they are to instill any iota of happiness into their children. Unfortunates are never convinced that true happiness comes from their own mental attitude rather than from an environmental heaven.

But dealing with the child and his family may not yield satisfactory adjustment. Contact may be necessary with special communal agencies, schools, psychiatric institutions, child guidance clinics, welfare agencies. But the competent staffs of many of these organizations have been disbanded at the onset of the depression. Relief agencies created provide mere maintenance, the benefits of which are minimal to children. Undernutrition persists, behavior problems multiply, disease and defectiveness spread. This devastation can be halted by material provision reinforced by supervised educational measures. Innumerable are the trained health workers who can serve the nation in this cause. Certainly practical methods can be formulated to help difficult families in both mental and physical health. In that realm remedies are clear-cut, yet no effort is made to apply them. With a sick world, faltering business and wavering counsels, protective health measures can be conscripted.

EVIDENCE FOR AN EXPANDING UNIVERSE

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THE astronomer's instruments are many and varied. Most important of all is the telescope itself; in addition, there are numerous auxiliary instruments and attachments, spectrographs in many forms and the equipment of the instrument and optical shop and of the modern physical laboratory.

MEASURING MOTIONS OF DISTANT UNIVERSES

At the Mount Wilson Observatory of the Carnegie Institution is the 100-inch reflecting telescope, the largest in the world. The great light-gathering power of this instrument has made it possible to investigate numerous problems which, except for a costly expenditure of time, could not have been carried on with smaller instruments. One of these problems is the motion toward us or away from us of the distant universes of stars which lie outside our own system or galaxy and are called the extra-galactic nebulae.

The first velocity of an extra-galactic, or spiral nebula, the Great Nebula in Andromeda, was measured by V. M. Slipher, of the Lowell Observatory at Flagstaff, Arizona, in 1912. It was already known that the spectra of these nebulae are similar to the spectrum of the sun, but the faintness of the nebulae had prevented the measurement of their velocities, until Slipher succeeded in reducing the necessary exposure by devising a very efficient camera for use with his spectrograph.

To obtain a photograph from which a velocity can be measured the feeble light from the nebula must be separated into its component colors by a prism. The two strongest lines crossing the spectrum, H and K produced by calcium, are usually the objects measured. If these lines are shifted to the violet from their normal position, the nebula is approaching; if shifted to the red, it is receding.

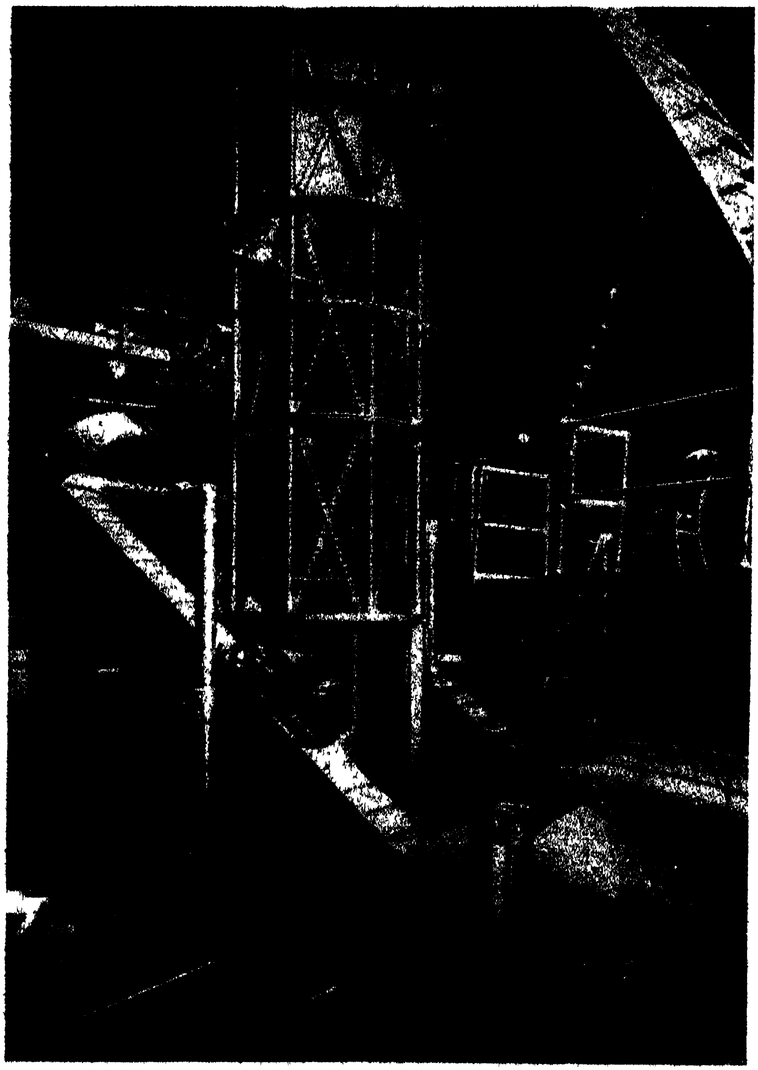
By 1925 the velocities of 45 nebulae had been measured, 40 of which were found to be receding into space with velocities ranging from only a few miles per second to as high as 1,100 miles per second, far higher than those of any other known astronomical bodies.

DETERMINING DISTANCE

In 1916, de Sitter, on the basis of relativity, had predicted that the spiral systems outside our own system should show receding motions which should be the greater, the greater the distance of the system. It was not then possible to test this predicted relation between distance and amount of motion because the distances of the spiral nebulae were not known.

The discovery of Cepheid variables in some of the nebulae by Dr. Edwin Hubble in 1923 removed this difficulty. The period during which the light of these variables changes tells how bright they are—their candle power; comparison of candle power with observed brightness gives the distance. Thus the Andromeda Nebula and Messier 33 were found to be at distances of about 870,000 light years, and hence must be systems similar in content and size to our own system.

Confirmation that these distances were essentially right was furnished by other individual stars that could be recognized in the nebulae, such as novae and the stars of very high luminosity. Continued study indicated that the nebulae themselves are all of the same general order of brightness and that differences in the total brightness of individual sys-



100-INCH REFLECTING TELESCOPE

The evidence for an expanding universe collected by Dr. Hubble and Mr. Humason was obtained with this instrument. Velocities of nebulae at distances up to 250 million light years can be measured, while direct photographs record still fainter nebulae at distances as great as 500 million light years.

tems is mainly an effect of distance. It thus gradually became clear that the brightness of a nebula is an excellent indication of its distance.

Relation Between Distance and Motion

The way was then opened for investigating the relation between distance and motion, and Hubble was soon able to derive for the nebulae then observed a linear relationship between velocity and distance within a region of space whose boundaries were defined by the most distant nebulae in Slipher's list. These were five nebulae in the Virgo cluster which Hubble had placed at a distance of about 7 million light years

The relation indicated that the velocities of nebulae increase at the rate of about 100 miles per second for every million light years of distance. The results also indicated that the velocity-distance relation, once established, could itself be used as a criterion of distance for all nebulae whose velocities were known.

The application of the new criterion to the nebulae in Slipher's list showed that in a general way the linear relation accounted fairly well for the observed velocities then available. The data were few, however, and further progress depended upon the extension of the observations to fainter and more distant nebulae, an investigation started at Mount Wilson in 1928, which would have been impossible except for the great optical power of the 100-inch telescope.

Nebulae occur as isolated objects, in groups and occasionally in great clusters, comprising 300 or more members, but when very large regions of space are compared, one region is very much like another Hubble's relation between velocity and distance could be tested in two obvious and straightforward ways. First by observing numerous nebulae in many different clusters and, second, by observing nebulae fainter than those included in Slipher's list, on the assumption that such objects are at greater distances and therefore should have larger velocities.

Observations of nebulae in clusters afforded the more important test. Distances are rather accurately measured by the mean apparent brightness of the many members in each cluster, while the distances of isolated nebulae are reliable only in a statistical sense. In fact, the distances of clusters are the only great distances that can be assigned with confidence to individual objects in the sky. Moreover, the selection of the brightest members in clusters insures maximum distance for any given apparent brightness

DEFINITE RESULTS OBTAINED

The first definite result was obtained in 1928 when members of a cluster in the constellation of Pegasus were found to be receding at an average rate of 2,400 miles per second, a value in good agreement with the estimated distance of the cluster, 23 million light years, and consistent with Hubble's conclusion that velocity increased with distance at the rate of 100 miles per second for every million light years of distance Further, observations of several very faint isolated nebulae all gave very large velocities, thus again confirming the velocity-distance relation.

It was then planned to extend the range in distance to the observable limit of the 100-inch reflector by measuring the velocities of the brightest members in faint clusters of nebulae, to investigate the differences, if any, in the velocities of bright and faint nebulae in selected clusters, and, finally, to obtain a large sample collection of velocities of both bright and faint isolated nebulae.

INCREASING INSTRUMENTAL POWER

The Mount Wilson observations used to test the relationship between velocity and distance had been obtained with the instrumental equipment then available at Mount Wilson. Although this equipment was powerful and efficient, it was necessary in order to obtain a single spectrogram for the measurement of the velocity of one of the fainter nebulae to extend the exposure over several nights. If still fainter nebulae were to be observed, it was clear that some further gain in instrumental power would be required.

This demand was supplied by a special objective for the camera of the spectrograph, designed by Dr. W. B. Rayton, of the Bausch and Lomb Optical Company, which led to a reduction of the exposure time to about one eighth that previously necessary.

Since 1929 when the Rayton lens was constructed the velocities of many faint isolated nebulae have been measured and, still more important, the observations of clusters of nebulae have been extended to include extremely remote objects. The list of clusters now observed is as follows:

Cluster	Distance in millions of light years	Velocity in miles per second
Virgo	7	750
Pegasus	23½	2,400
Pisces	24	2,900
Cancer	29	3,000
Perseus	36	3,200
Coma Berenices	45	4,700
Ursa Major No 1	84	9,500
Leo	105	12,000
Gemini	114	15,000
Corona Borealis	120	13,000
Bootes	230	24,400
Ursa Major No 2	240	26,000

RECESSION VELOCITIES

At present the velocities of 189 extragalactic nebulae are known, of which 146 have been obtained at Mount Wilson since 1928. The observations cover a range in distance which is thirty-five times that available when Hubble first formulated the velocity-distance relation and indicate that out to the second Ursa Major cluster, at a distance of 240 million light years, the increase in velocity is still sensibly proportional to the increase in the distance. The recent observations change the rate of increase in velocity but little, from 100 to 110 miles per second for every million light years of distance. These observations extend to, or at least close to, the limit of present instrumental equipment and any serious revision of the relation must await the completion of a larger telescope.

In a single cluster, the Virgo cluster, over 30 velocities are now known. These velocities show an average range of 310 miles per second around a mean of about 750 miles per second, and in addition that the mean velocity of the faint nebulae is approximately the same as that of brighter nebulae in the cluster. Of the 189 velocities now known only 13 are velocities of approach, all of nearby nebulae for which the random part of the motion is larger than the part which depends upon the distance of the nebula.

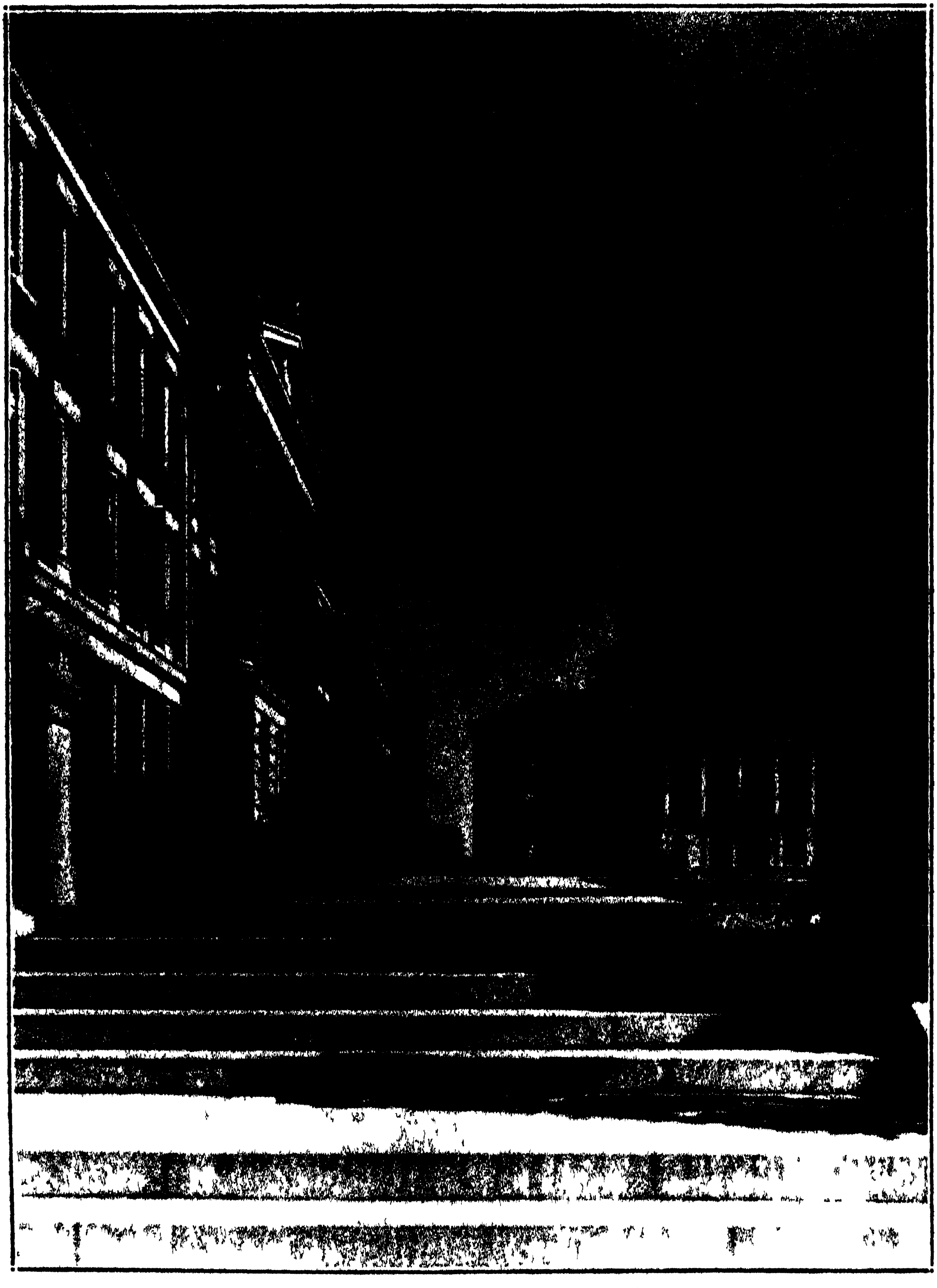
Practically all the photographs were made with the 100-inch reflector. The photographic plate used is ½ × 1½ inches. The length of the spectrum is slightly over 2/25 of an inch, and the exposure times range from 2 to 60 hours.

Nebulae in the two most distant clusters are too faint to be seen with the 100-inch reflector and were centered on the slit of the spectrograph by setting off the distance of the nebula from the nearest bright star as measured on a direct photograph of the field. Both of the objects measured in these two clusters are about 30,000 time fainter than the faintest stars seen with the naked eye.

INTERPRETATION STILL CONTROVERSIAL

Finally, it should be noted that the observational fact of the investigation is a close relationship between the brightness of a nebula and a shift of its spectral lines toward the red. Differences in brightness, in general, may confidently be interpreted as indicating differences in distances for the different nebulae, but the interpretation of the red-shifts as velocities of recession is still controversial.

On the other hand, if the interpretation of velocity-shifts as a motion of recession is abandoned, we find in the red-shifts a hitherto unrecognized phenomenon whose implications are unknown. The expanding universe of general relativity would still persist in theory, but the expansion would not then be indicated by the observations.



THE LATTIMORE HALL OF CHEMISTRY
WITH THE RUSH RHEES LIBRARY IN THE BACKGROUND

THE PROGRESS OF SCIENCE

THE ROCHESTER MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

FOR the second time in its history, Rochester, New York, welcomed the American Association for the Advancement of Science for a summer meeting. The first was held in the summer of 1892 and was the forty-first meeting of the association. The meeting just past was the ninety-eighth and was held in Rochester, from June 16 through June 18, following which the delegates journeyed to Ithaca to participate in the semi-centennial anniversary of Sigma Xi, held at Cornell University on June 19 and 20.

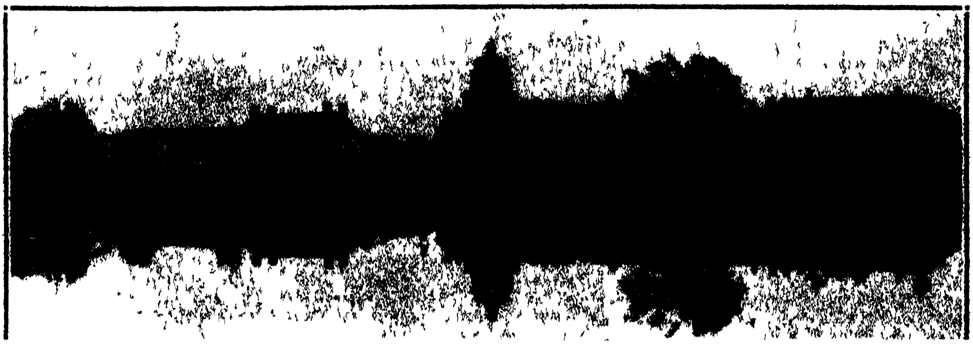
The city of Rochester, with a population of about 400,000, is located at the falls of the Genesee River, extending along its banks for about ten miles to its mouth on Lake Ontario. It is in many ways an ideal location for a summer meeting because of its normally mild summer climate and its location within easy reach of the Lake Ontario beaches, the famous Finger Lake region and other points of scenic interest, such as Niagara Falls and the Letchworth State Park.

Industrially the city of Rochester is of unique interest to scientists, being the home of the Eastman Kodak Company, the Bausch and Lomb Optical Company, Taylor Instrument Companies, the Ward Natural Science Museum, the Stromberg-Carlson Radio Company and other scientific centers. Excursions were arranged to the factories and research laboratories of most of these companies.

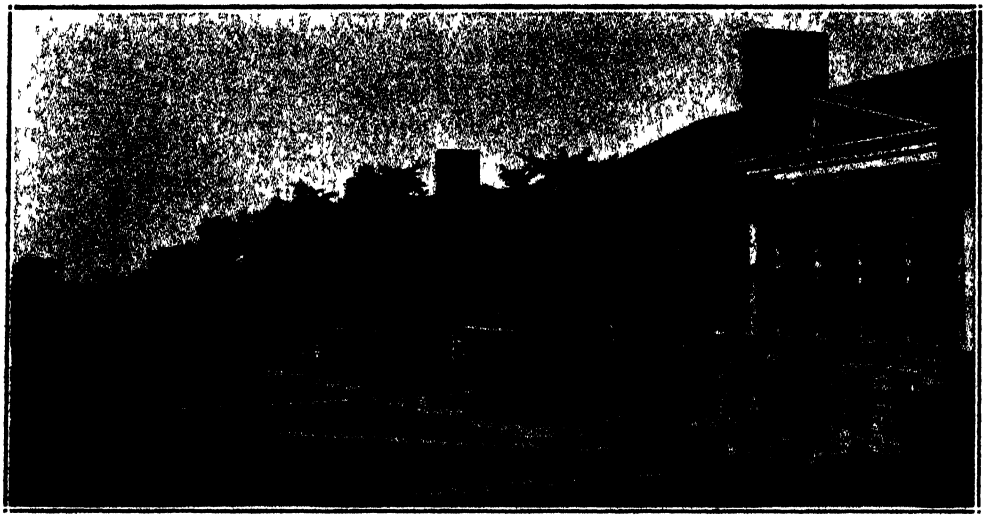
The University of Rochester, which was host to these meetings, is a non-denominational, privately endowed institution organized in 1850. As a result of generous gifts to the late George Eastman and of an extensive endowment campaign in 1920 the university has undertaken a considerable expansion of its activities since that time. It now consists of the College of Arts and Science, the Eastman School of Music and the School of Medicine and Dentistry.

The section meetings were held at the new River Campus of the College for Men and at the School of Medicine on adjoining grounds. The River Campus, which was first occupied in 1930, is located on a beautiful site overlooking the Genesee River and includes an exceptionally fine group of modern college buildings. Most of the science research laboratories are located on this campus.

The School of Medicine occupies a new group of buildings located within five minutes' walk of the River Campus. These buildings were erected in 1924 at the time the Medical School was organ-



RIVER CAMPUS FROM ACROSS THE GENESEE RIVER



EASTMAN QUADRANGLE OF THE RIVER CAMPUS

ized and contains some of the most modernly equipped medical research laboratories in the country The Strong Memorial Hospital of the University of Rochester and the Rochester Municipal Hospital are included in this group

The three evening meetings were held in the beautiful Eastman Theater. On Tuesday evening, June 16, Dr. C. E. K. Mees, director of research of the Eastman Kodak Company, spoke on "Color Photography." The Maiben lecture, held the following evening, was given by Dr Charles Camsell, Deputy Minister of Mines of Canada His subject was "A 4000-mile Flight over Northwestern Canada." This was followed by a reception given by President Alan Valentine and the trustees of the University of Rochester in the promenade of the Eastman School of Music Dr. Carl Snyder, of the Federal Reserve Bank of New York, spoke on Thursday evening on "The Rôle of Capitalism in Civilization."

A symposium on "Flood Control" was one of the features of the meetings. The speakers were Dr. F. A. Silcox, chief of the National Forest Service, Dr. W. C. Lowdermilk, associate chief of the U. S. Soil Conservation Service, and Dr. Morris L Cooke, administrator of the Rural Electrification Administration.

A symposium on "Social Security" attracted a good deal of attention. Another interesting event was the balloon ascension on Wednesday afternoon, June 17. Two high altitude radio-equipped balloons were released in order to continue lines of study inaugurated in the recent stratosphere flight and to record weather conditions.

On Thursday noon, June 18, at a complimentary luncheon at the Oak Hill Country Club to all delegates, the Bausch and Lomb Optical Company presented its 250,000th microscope, the culmination of sixty years of endeavor, to Dr. F. G. Novy, professor of bacteriology of the University of Michigan, in view of the fundamental significance of the researches he has made.

Thirty technical sessions were held, at which 200 papers were presented. These included special symposia on such subjects as weather forecasting, geophysics, biophysics, geology of New York State, dental caries, aerial photogrammetry and recent advances in medicine and bacteriology.

J. Edward Hoffmeister,
Chairman, Local Committee

MEDALLISTS OF THE NATIONAL ACADEMY OF SCIENCES

THE practice of awarding medals is an old one. A medal is given to an individual either in recognition of distinguished service or in commemoration of an important event. Medals were first bestowed as rewards for military services rendered to King and country, the "Armada" medals of Queen Elizabeth being among the earliest of this type. During the next century medals continued to be awarded almost exclusively to men of the military forces; but gradually the importance of services, other than military, to the state were realized and medals were bestowed on civilians. The Royal Society awarded its first medal, the Copley, in 1731 to Stephen Gray; in 1753 this medal was awarded to Benjamin Franklin The National Academy of Sciences awarded its first medal, the Henry Draper, in 1885 to S P Langley in recognition of his researches "in solar physics and especially in the domain of radiant energy " This medal had been made possible through a fund of six thousand dollars presented to the academy in 1883 by Mrs Mary Anna Palmer Draper for the purpose of establishing a gold medal to be awarded to "any person in the United States of America or elsewhere who shall make an original investigation in astronomical physics, the results of which shall be made known to the public."

At the present time the National Academy of Sciences administers ten funds, the income from which is intended for use in connection with the award of medals in specified fields of science. Several of these funds provide honoraria in addition to the medals. Thus far the academy has awarded 102 medals in honor of scientists whose research work has contributed notably to advance of knowledge.

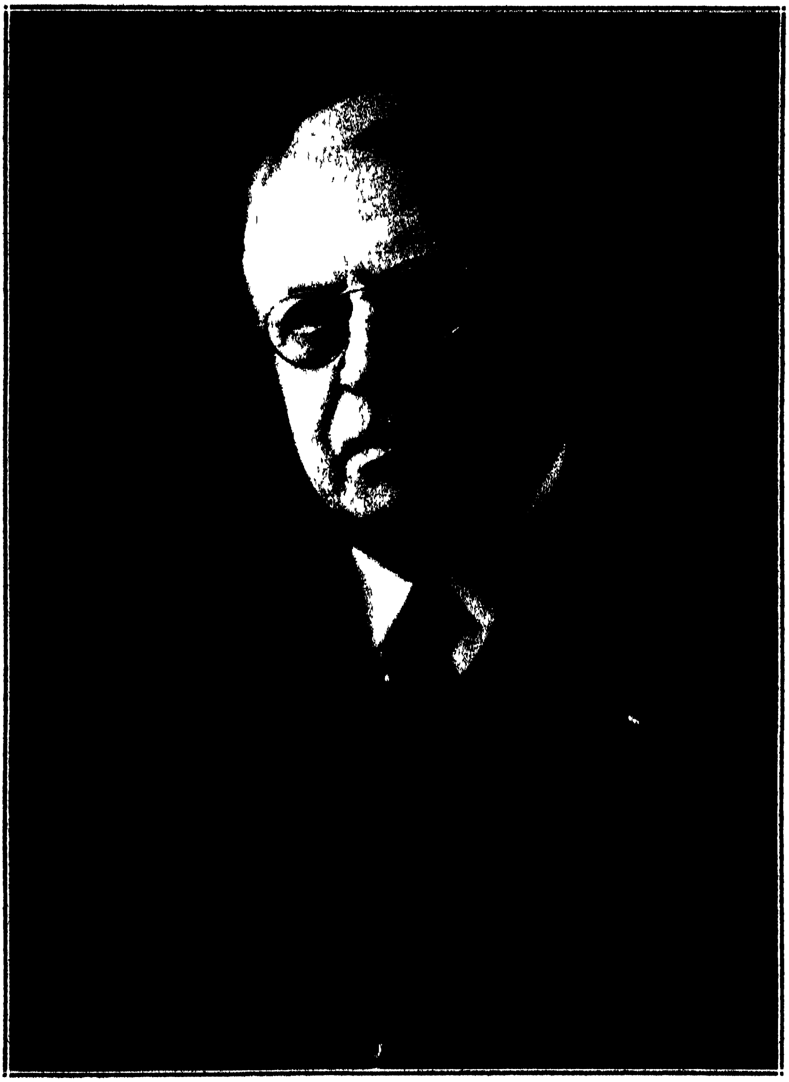
At the seventy-third meeting of the National Academy of Sciences, held this year from April 27 to 29 in Washington, two medals were presented: The Agassiz Medal for Oceanography, awarded to Dr. T. Wayland Vaughan, director of the Scripps Institution of Oceanography of the University of California, La Jolla, California, "in recognition of his investigations of corals, foraminifera and submarine deposits and for his leadership in developing oceanographic activities on the Pacific Coast of America"; the Public Welfare Medal of the Marcellus Hartley Fund, "awarded to Dr. F F Russell, formerly director of the International Health Division of the Rockefeller Foundation and at present lecturer in preventive medicine and hygiene and epidemiology at Harvard University, Cambridge, Masachusetts, in recognition of his work on the etiology of yellow fever and studies of epidemic areas."

Dr. Henry B. Bigelow, member of the Murray Trust Fund committee which recommended the award of the Agassiz Medal for Oceanography to Dr. Vaughan, referred in his presentation speech to the fact that "the oceanographer is constantly reminded that understanding of the margins of the oceans and of the parts of the earth's crust on which the latter rest is as integral a part of his science as is examination of the waters themselves, for these geologic features determine the extent, depths and circulatory systems of the oceans with all that this implies. Conversely, we can not hope to understand the geology of continents or of islands until we understand the structure and history of continental shelves, of ocean floors or of the corrugations of the latter. It is, therefore, eminently fitting that the academy should honor one who, commencing his career as a geologist, soon turned to the geologic history of shore lines and of the sediments of the seas—especially when we remember that the donor of the medal, Sir John Murray, was himself the most eminent student of oceanic deposits. We see Vaughan's genius and the part he has played in the progressive unfolding of submarine geol-

DR. T. WAYLAND VAUGHAN

ogy in his studies of the corals and coral reefs of past ages, of the history of the islands of the West Indies and of the Floridian almost-island; of the organic skeletons that accumulated on the sea floor in past geologic ages, as exemplified especially by the fossil Foraminifera; leading, in order of evolution, to his examination of modern sediments, Atlantic and Pacific.'' Dr. Bigelow emphasized further the part played by Dr. Vaughan in building up the Scripps Institution and to its achievements during his directorship in adding to ''knowledge of Pacific circulation in general, of California up-welling waters and their effects on organic fertility, of ocean dynamics, of the interrelation between sea temperatures and meteorologic phenomena.''

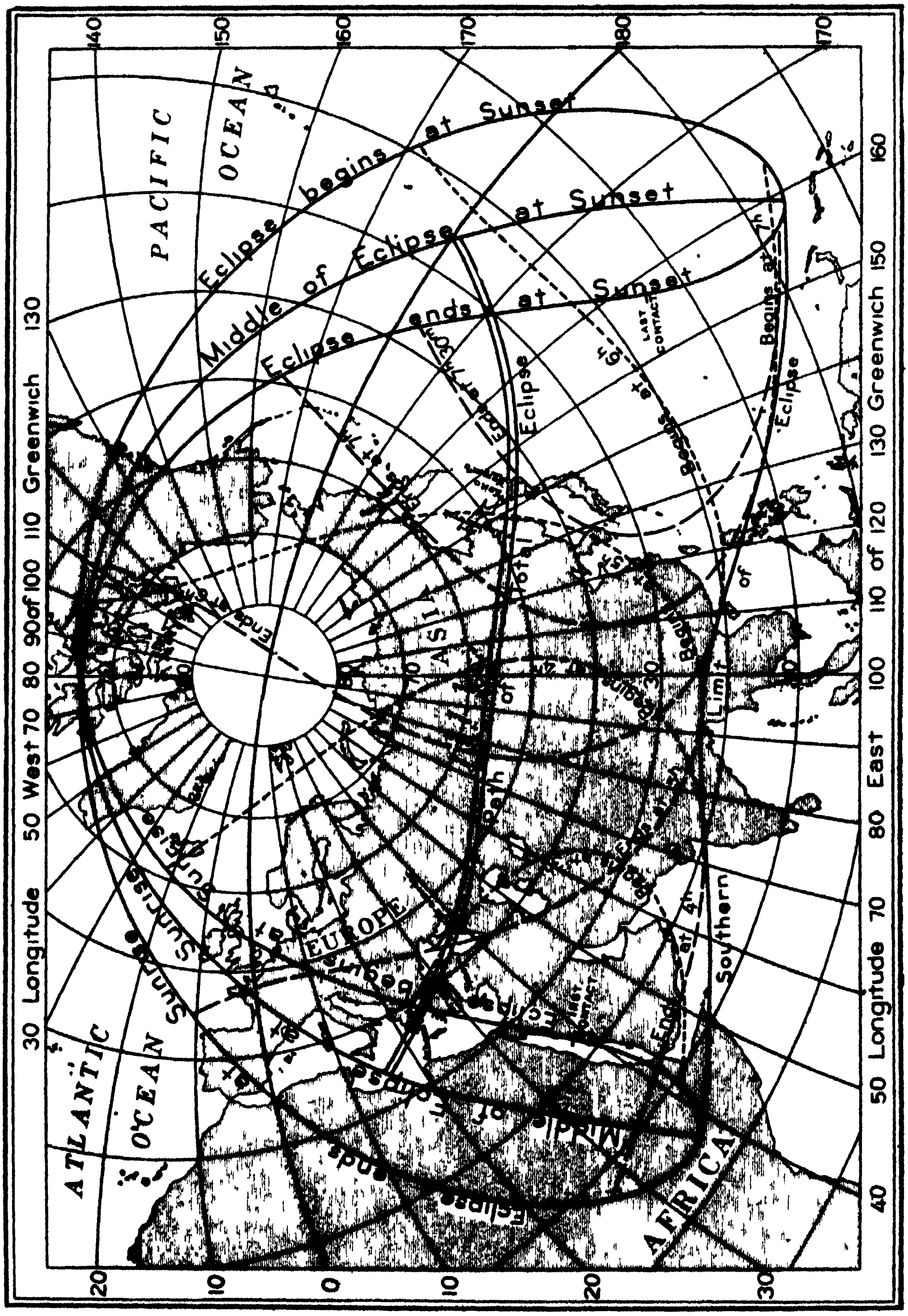
In his presentation speech, Dr. Max Mason, member of the Marcellus Hartley Fund committee which recommended the



DR. F. F. RUSSELL

award of the Public Welfare Medal to Dr. Russell, remarked, by way of introduction, that "the curiosities which stimulate the development of the sciences are sometimes derived from abstract contemplation of the known facts and their cataloging concepts. These curiosities arise with compelling insistence, however, when a scientifically conceived attack on an important practical problem reveals the inadequacies of existing knowledge. The achievements of Frederick Fuller Russell are important examples of the successful application of science to human welfare and illustrate the advance of science through interplay of theory and practice." From 1920 to 1936 Dr. Russell was director of the International Health Division of the Rockefeller Foundation.

In the words of Dr. Mason, "Russell brought to the Foundation high abilities for administration as well as unusual aptitude and training in scientific medicine.


PACIFIC OCEAN
ATLANTIC OCEAN
ASIA
EUROPE
AFRICA
Eclipse begins at Sunset
Middle of Eclipse at Sunset
Eclipse ends at Sunset
Path of Total Eclipse
Southern Limit of Eclipse
Eclipse begins at Sunrise
Middle of Eclipse at Sunrise
Eclipse ends at Sunrise
Begins at 7h
Begins at 4h
Ends at 4h
LAST CONTACT
FIRST CONTACT
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U. S. Naval Observatory

THE PATH OF THE JUNE ECLIPSE

THE HOURS OF BEGINNING AND ENDING ARE EXPRESSED IN GREENWICH CIVIL TIME

Under his direction the International Health Division continued its sympathetic and understanding cooperation with governments in building up public health organizations and in training public health personnel, and intensified the efforts of its own staff in disease control. To Russell disease control meant the study of disease in its own environment, by men of thorough scientific competence This field work was backed by basic laboratory work at home and constant interplay between field and laboratory ensured the rapid application in the field of new laboratory findings, while the studies and experiences in the field stimulated new research at home Only by insistence upon this unity of effort could such remarkable progress have been gained in the etiology and control of malaria and yellow fever as was accomplished by the staff during Russell's leadership. . . . Such is the nature of the work of Russell, the scientist and the administrator. Those of us who have counted him as a colleague and love him as a friend alone know the full measure of the man.''

In his response, Dr. Russell commented on the cooperative aspects of the public health work and on the nature of the problems which were attacked under his direction. To quote his words. ''I realize as you all do, that the medal is given me because I was the director of a group of workers, and that the honor is for the group and that on this occasion I merely represent it.'' His address ended in the same key. ''Again Mr President, I thank you for the honor and for this opportunity of speaking for my coworkers.''

F. E. Wright,
Home Secretary

ECLIPSE EXPEDITION TO THE U. S. S. R.

Two expeditions to observe the total eclipse of the sun on June 19 have been sent to Soviet Russia by the National Geographic Society in cooperation with Georgetown University and the National Bureau of Standards.

The National Geographic-Georgetown Expedition will be located near Kustanai, U. S. S. R., northeast of the Caspian Sea. Its leader is Dr. Paul A McNally, director of the Georgetown College Observatory, Washington, D. C.

The program of this expedition includes spectroscopic analysis of the light of the sun's corona, direct photographs of the eclipse, both in black and white and in color, photometric measurements of the intensity of light at various stages of the eclipse and timing of the contacts of the sun and moon at the beginning and ending of the eclipse.[1]

The duration of totality in the vicinity of Kustanai will be 127 seconds. Meteorological data based upon observations during several years past and made available by the Government of the U. S. S. R. show a high probability of clear weather at the time of the eclipse in this region.

In addition to attempting direct color photographs of the eclipse the expedition will make a series of pictures with special filters sensitive to various wave-lengths of light. These pictures will be in black and white, but the degree of blackness on each plate will show the intensity of the particular color that registered predominantly on each particular plate. Then by comparison with a scale of intensity of black and white the proper shade of color for each picture can be determined and added. Superimposing all the plates, each with a different color of the spectrum, should provide a synthetic picture of the eclipse in its actual colors. This method of capturing the colors of the eclipse never has been attempted previously.

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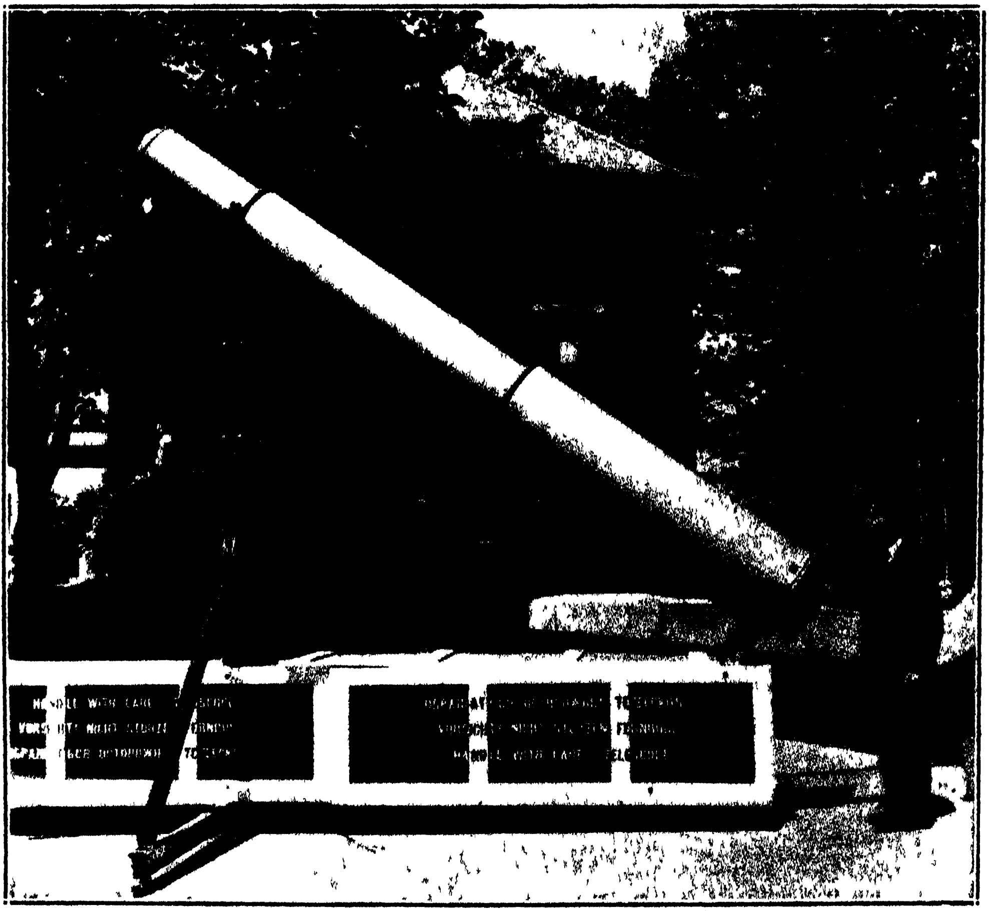
[1] Totality will occur at Kustanai at 8: 24: 56 8 A.M., June 19, in terms of World Standard Time. This corresponds to 11: 24: 56.8 P.M., June 18 Eastern Standard Time in the United States. Since clocks in Russia were set ahead permanently one hour in 1930 by Government order, the official time of totality, measured locally in Kustanai, will be 9: 24: 56.8. Totality will occur at Ak Bulak a little more than an hour earlier than at Kustanai.

In the direct photography of the eclipse a panatomic emulsion of extremely fine grain will be used for the first time in eclipse photography, making possible enlargement of the photographs approximately 500 times, a greater enlargement than previously has been attained in eclipse work.

The expedition also will use photographic emulsions new to eclipse photography for registering the "flash spectrum" which becomes visible just before the moon completely covers the face of the sun. With the new emulsions it is hoped to record invisible infra-red light of the flash spectrum up to wave-lengths of as much as 12,000 Angstrom units, several thousand Angstroms farther out toward the infra-red than has previously been accomplished in recording the flash spectrum.

The timing of the eclipse will represent a special investigation on behalf of the United States Naval Observatory, and the observatory will broadcast special radio time signals with special intensity as an aid to this program.

The corona, always one of the most



National Geographic Society

DR. IRVINE C. GARDNER
WITH THE 14-FOOT CAMERA

National Geographic Society

DR PAUL A. McNALLY

WITH THE TELESCOPE AND OTHER EQUIPMENT

interesting features of an eclipse of the sun, is expected to be roughly square in shape during this year's eclipse instead of extending outward in long streamers, as was the case in the eclipse of 1932 The shape of the corona varies with the progress of the 11-year sun-spot cycle, and the long streamers appear when the spots are approaching a minimum, whereas this year the spots are on the increase.

The National Geographic-Georgetown Expedition will have more than four tons of equipment. Its personnel, in addition to Dr. McNally, includes: Emeran J Kolkmeyer, Thomas J. Smith and Carl H. Spriegel, of Georgetown University, and William Robert Moore, of the National Geographic Society.

The National Geographic-Bureau of Standards Expedition will be in charge of Dr. Irvine C. Gardner, of the Bureau of Standards, assisted by Mrs. Gardner, who is, herself, a qualified scientist. Their headquarters will be at Ak Bulak, U S S R., about 370 miles southwest of Kustanai.

The Gardners will photograph the sun's corona by means of a 14-foot camera equipped with a newly designed astrographic lens, and designed to make photographs both in black and white and in color. The camera is mounted on a rigid demountable frame consisting in part of the cases in which it was shipped. Construction of the camera and its mounting as a single rigid unit has enabled the focusing and other adjustments to be made before leaving the United States, greatly reducing the time required for preparation in the field.

The new lens greatly reduces the necessary focal length and increases the speed of the photography. The lens will provide an image of the sun two inches in diameter on the photographic negatives, which will make possible enlargement sufficient to bring out considerable detail.

The photographs taken with this camera also will be used to measure the brightness of the corona at various distances from the sun. The intensity of black and white registered on the photographic plates when compared with a scale of various degrees of black and white will indicate the intensities of light which correspond to the degrees of the scale.

Ak Bulak, where Dr. and Mrs. Gardner will be stationed, also will be the headquarters of the joint expedition of Harvard University and the Massachusetts Institute of Technology.

M. K.

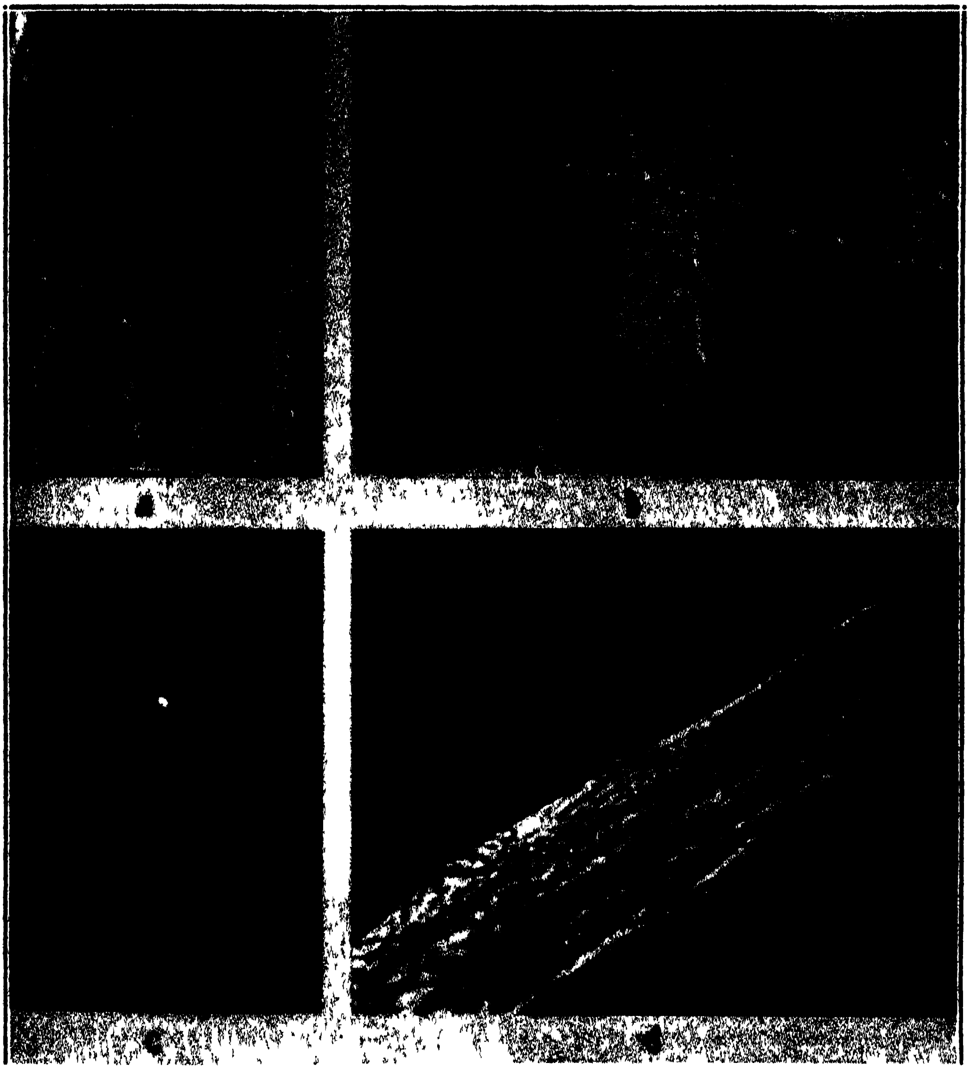
THE STRUCTURE OF "CELLULOSE"

THE important fact that the tissues of plants and animals are developed through the division, differentiation and enlargement of diminutive unit structures named "cells" is one of the major contributions of biological research of the past century. Before 1850 many of the structural variations of the cells themselves had been observed with the microscope and accurately described The boundary of the animal cell was found, ordinarily, to be a thin, delicate membrane, while that of the plant cell was usually conspicuous, often quite rigid, and was referred to as the "cell wall."

The presence of crystalline material in this cell wall was quickly recognized by its appearance in polarized light. Its swelling behavior in water indicated a physical rather than a chemical change. A "micellar theory" based upon the idea that the wall was made up of submicroscopic crystalline particles (micellae) which were pushed apart by but did not react with the water was therefore elaborated Subsequent workers have found that this crystalline material in the wall is a compound of carbon, hydrogen and oxygen It is produced exclusively through the activity of the living protoplasm of the plant cell and has been named "cellulose."

Botanists have been interested in the structure and chemical nature of the cellulose membrane because all outside influences first encounter this wall and may change or be changed by it before reaching the interior of the cell. These reactions have been difficult to evaluate because of the supposed invisibility of the fine structure of the wall. Chemists have followed the behavior of the wall material with a large variety of techniques, have produced many valuable derivatives and have attempted, without success, the synthesis of a similar substance from the elements which compose it Difficulties likewise have arisen in the interpretation of the many types of membrane behavior thus encountered.

Recent investigations of Wanda K. Farr and Sophia H Eckerson, of the Boyce Thompson Institute for Plant Research, have led to a new conception of cell wall structure. The building up of the wall from small ellipsoid granules of cellulose surrounded by a glue-like substance has been observed in the living cell. The "cellulose particles" are joined together in a single row, end to end, to form a fibril and the fibrils in turn are joined laterally to form each layer of the wall. The particles constitute the crystalline and the cementing material the non-crystalline portions of the membrane. When the cell wall is immersed in water the particles themselves are not affected but are seen to be pushed apart by the swelling of the colloidal cementing material. The fine structure of the cell wall is therefore visible instead of invisible. The separated particles exhibit all the specific properties of cellulose, and the separated cementing material proves to be a jelly-like substance similar to the pectic material which is extracted from citrus fruits and apples. The reactions of the two separable wall constituents are remarkably consistent. It is not difficult to demonstrate that many of the inconsis-



CELLULOSE PARTICLES

a. In a living cell. b From the wall of a cotton fiber. c, d A single particle and a disintegrating cotton fiber in polarized light.

tencies of past analyses of entire cell walls have been the result of mutual contamination. The various problems of cellulose chemistry will be reinvestigated in the light of the results of these observations.

FLUCTUATIONS OF ELECTRICAL POTENTIAL IN THE CORTEX OF THE BRAIN

The human electroencephalogram has recently been studied at the Harvard Medical School by Dr. Hallowell Davis and his associates both from the point of view of the normal, and epileptic individual. Preliminary experiments confirmed the observations of Berger, Adrian and others that fluctuations in electrical potential of as much as 50 microvolts could be recorded from the human head with skull and scalp intact, and also that this activity does not originate in skin or muscle, but in the cortex of the brain. The commonest recognizable pattern is a series of regular waves at a frequency of about ten a second. This pattern, sometimes known as the "alpha" rhythm, is best seen when the subject is physically and mentally at ease with eyes closed. It is suppressed, temporarily at least, by opening the eyes, or by any sensory stimulation or mental activity which sharply engages the subject's attention. Many subjects show it rarely, if at all, even under the most favorable conditions. Other waves of various amplitudes, sometimes at regular frequencies of about 20 to 30 per second (the "beta" waves) and sometimes quite irregular, also appear, either with or without the "alpha" waves. In general, the pattern of activity taken over a period of time from a given area of the skull is characteristic of a given individual.

A number of states involving more or less complete impairment of consciousness, such as fainting, anesthesia and early sleep, show first a loss of the ten-a-second rhythm and then the development of longer and larger waves, sometimes quite regular at about two or three a second.

Epilepsy shows very characteristic patterns. *Petit mal* in particular yields, during the seizure, a very regular series of large waves at the frequency of three a second, each wave accompanied by one or more sharp spikes. The details depend on the individual and on the region of the brain examined, but the general pattern is so highly characteristic of *petit mal* as to be a useful aid in diagnosis. Minor "seizures" with little or no external manifestation may be detected, and the modifications produced by sleep, mental activity, drugs, etc., readily ascertained. A report of such studies was presented at the American Medical Association in Kansas City in May, 1936.

Grand mal epilepsy also presents a characteristic pattern of intense electrical activity building gradually to a climax and then subsiding. This pattern is very similar to the electrical "storms" which may be induced experimentally in certain animals by convulsant drugs or mild damage to the cortex. The latter phenomenon has been described in some detail by Fischer and by Kornmueller in Germany.

The electroencephalogram seems to hold great promise for the physiologist and for the psychologist in the study of normal function and for the neurologist in the study of epilepsy and other abnormal conditions, and work is actively in progress along these lines in many laboratories both in this country and abroad.

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NUTRITIONAL IMPROVEMENT IN HEALTH AND LONGEVITY

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THIS article is essentially a report, interpretive rather than technical, upon the investigation of the relation of food to health and to length of life, which is being conducted at Columbia University with the cooperation of the Carnegie Corporation of New York and the Carnegie Institution of Washington. This is, of course, but one among several Carnegie researches in nutrition.

Practically throughout its history, the Carnegie Institution of Washington has supported nutritional research: in the energy aspects, first by grants in aid of the work of Atwater and Benedict at Wesleyan University, and then by the establishment of its own Nutrition Laboratory in Boston under the direction of Dr. Francis G. Benedict; in the aspects having to do chiefly with the proteins and vitamins, by liberal grants in support of the work of Osborne and Mendel at Yale and the Connecticut Agricultural Experiment Station; while grants in aid of research upon enzymes at Columbia contributed toward the working out of the chemical natures of substances important to the nutritional process both as protein derivatives and as catalysts of the body's chemical reactions without which these would not run fast enough to support such a rate of energy exchange as is essential to the higher forms of life.

ADEQUATE AND OPTIMAL DIETS

The work now to be summarized is a joint outgrowth of these earlier Carnegie researches and of the nutritional aspects of certain food supply problems of the world war (Figs. 1–3). One of these problems was. What minimum proportion of milk suffices so to supplement or balance a maximum proportion of wheat that the mixture will constitute a nutritionally adequate diet?

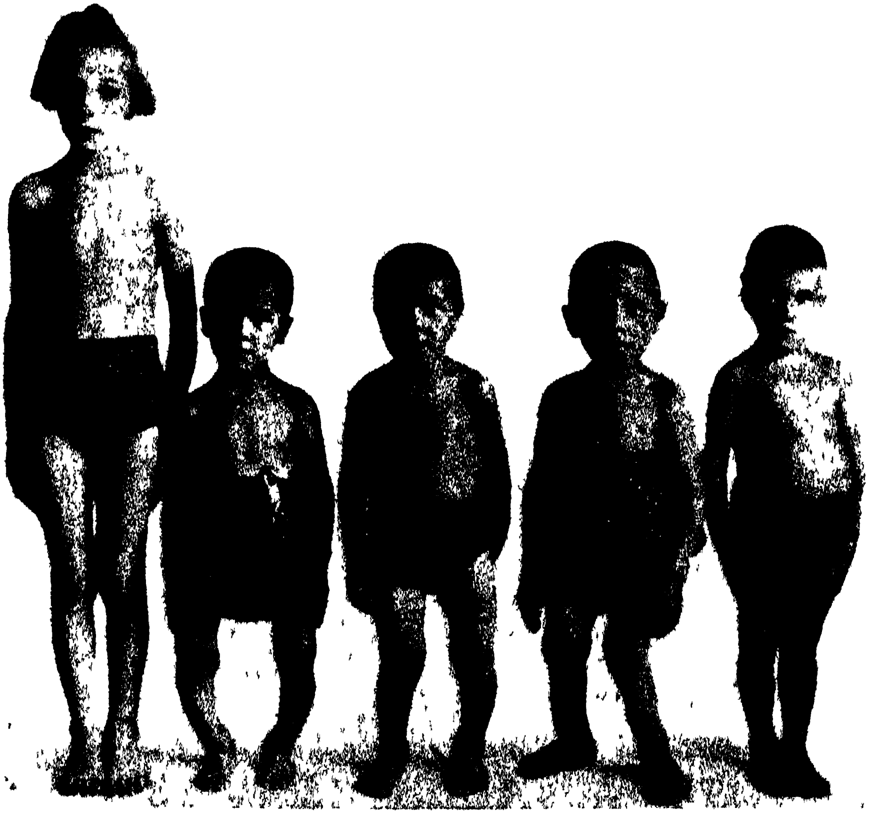
It was found that a mixture of five sixths ground whole wheat and one sixth dried whole milk, with table salt and distilled water, which we shall call *Diet A*, was adequate in that it supported normal growth and health with successful reproduction and rearing of young, generation after generation. Yet when the proportion of milk was increased, to constitute *Diet B*, the average results were better.

Diet A, then, is adequate but not optimal; Diet B is better and probably capable of still further improvement. We have here a nutritional improvement upon a dietary which was already adequate. In the averages of sufficiently large numbers of cases the evidences of nutritional improvement are measurable in terms of several criteria of increased vitality at different stages of the life cycle, and the measured differences are such as to show that, within the range or zone of normal nutrition and health, there is a rather large area between the merely adequate and the optimal. It is the exploration of this area with which we are here concerned.

THE EXPERIMENTAL ANIMAL

The experimental animal chiefly employed has been the rat; because, as had been shown by the work of Osborne and Mendel and of Folin, the chemistry of its nutrition is so closely similar (in nearly all respects) to that of the human being.

Chemically, the only way in which this experimental animal has been found to differ materially from ourselves is that we are much more dependent upon, and responsive to, the vitamin C value of our food. Thus the opportunity for nutritional improvement is similar on the whole in the two species; but where they differ the responsiveness of the human organism is the greater. Hence definite scientific evidence supports the view that the laboratory findings need not be discounted when applied to human prob-



Courtesy Extension Service, U. S. Dept. of Agriculture.

FIG. 1. EFFECT OF DEFICIENT DIETS.

FIVE AUSTRIAN CHILDREN, ALL SEVEN YEARS OF AGE. WITH FOUR OF THEM SUCH FOOD SHORTAGES AS LACK OF MILK AND EGGS MARKEDLY INFLUENCED GROWTH AND DEVELOPMENT.

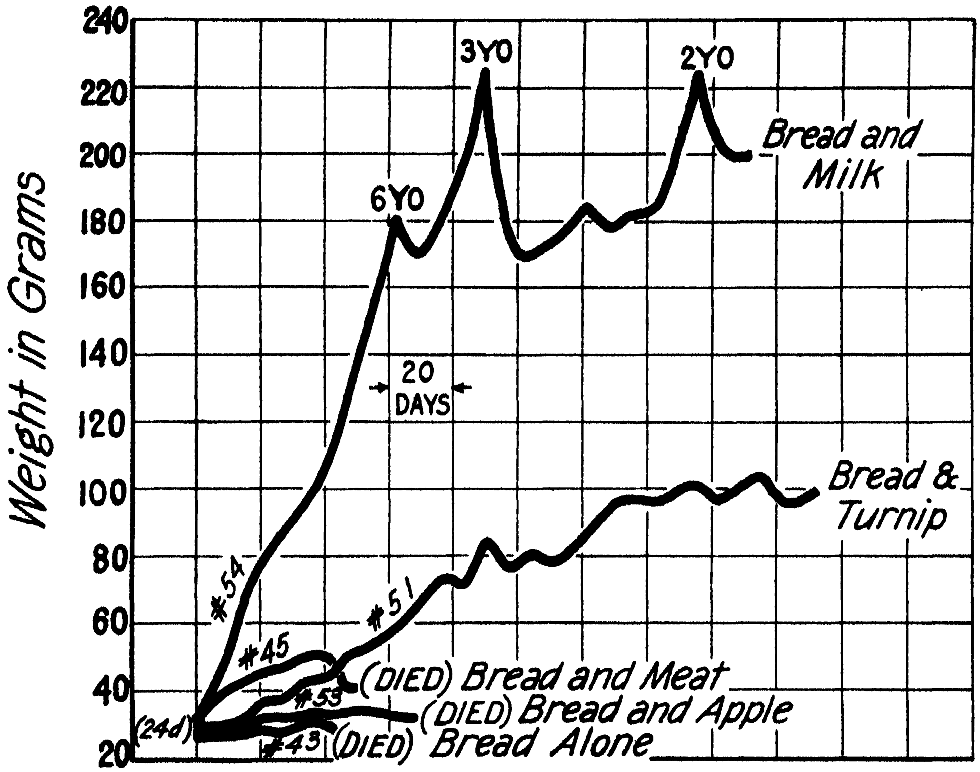


FIG 2. RESULTS ON RATS OF A DIET OF BREAD ALONE OR OF BREAD WITH ONE OTHER FOOD

AS SHOWN HERE, MILK PROVED ESPECIALLY EFFECTIVE IN NUTRITIONALLY "BALANCING" BREAD. IN EACH OF THESE EXPERIMENTS WITH BREAD AND ONE OTHER FOOD, THE BREAD FURNISHED FOUR FIFTHS AND THE OTHER FOOD ONE FIFTH OF THE TOTAL FOOD CALORIES.

lems; more probably they are considerably *within* the truth as to the responsiveness of human health to nutritional improvement.

The fact that the rat, while resembling us so closely in its chemistry, yet runs through its normal life cycle in one thirtieth the time of a human life adds, of course, very greatly to the facility with which this deputy can be employed in the experimental study of our nutritional problems. If it were possible to observe human subjects under controlled conditions through entire life cycles for successive generations, centuries would be required to cover the ground covered by the laboratory work of the decade or so which we are here reviewing. Moreover, these laboratory animals are sufficiently modest in their demands for space and cost of living to permit of the use of large enough numbers to justify confident statistical interpretation of findings.

IMPROVEMENT RESULTING FROM CHANGE OF DIET

Several differences in degree of nutritional welfare and resulting health, within the range of what is accepted as normal, have now been thus established.

The first of these differences which we observed was that, in the launching of a new generation, Diet B supports the

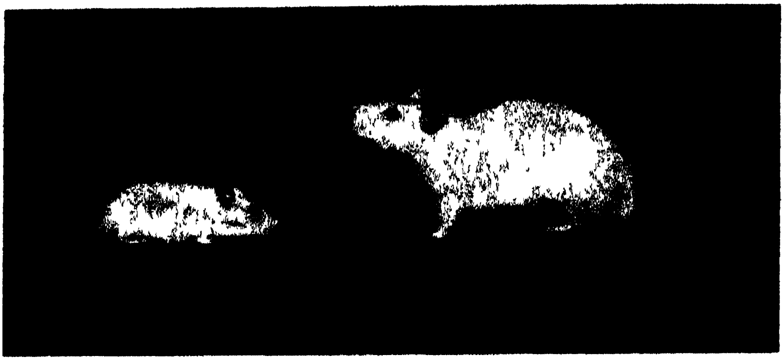


FIG. 3. FROM THE SAME LITTER.

THESE TWIN SISTERS HAD BEEN OF THE SAME SIZE AND EQUALLY HEALTHY AND VIGOROUS AT THE BEGINNING OF THE EXPERIMENT SUMMARIZED IN FIG. 2; THEN DURING THE EXPERIMENTAL PERIOD ONE WAS FED BREAD AND APPLE, THE OTHER BREAD AND MILK. THE LATTER MADE GOOD GROWTH AND APPEARED HEALTHY AND NORMAL IN EVERY WAY. WITH THIS LIMITED PROPORTION OF MILK, HOWEVER, IT WAS ONLY WHEN WHITE BREAD WAS REPLACED BY WHOLE WHEAT THAT THE DIET BECAME ADEQUATE FOR THE SUPPORT OF SUCCESSIVE GENERATIONS.

mother better than does Diet A, and at the same time gives the young a better start (Fig 4).

Strictly quantitative experiments with large numbers of such families continuing through successive generations and covering (of late, at least) the entire life cycle of each individual, showed that this same improvement of an already adequate diet (1) expedited growth and development, (2) resulted in a higher level of adult vitality as shown by several criteria, and (3) extended the average length of adult life, or improved the life expectation of the adult. Data on the first and second of the three phases just mentioned have been summarized in a previous report,[1] while the data for length of life are shown in Table I.[2]

TABLE I

SHOWING INCREASE IN LENGTH OF ADULT LIFE THROUGH IMPROVEMENT OF AN ALREADY ADEQUATE DIETARY

	On Diet A		On Diet B		
	Number of cases	Average length of life in days	Number of cases	Average length of life in days	Difference of length of life in days
Males..	135	571 ± 8.0	124	635 ± 8.5	64 ± 11.7
Females	196	603 ± 8.0	163	669 ± 7.8	66 ± 11.2

The increase in average length of adult life here found would correspond to an extension of the long-standing human-adult life expectation of 70 years to 77 years instead Obviously many cases of people living to the age of 77 fall within the familiar range of normal experience. Yet inasmuch as previous improvements in the average length of life have been so closely confined to the lowering of *early* death rates as to leave the average length of *adult* life unchanged, the possibility of extending this *average* by nutritional improvement is of interest from several points of view.

It is all the more significant because of the fact that, in these experiments, development is expedited and senility deferred in the same individuals, so that what, for lack of a better term, we may call "the period of the prime" is extended in greater ratio than the life-cycle

[1] H. C. Sherman and H. L. Campbell, *Jour. Biol. Chem.*, 60: 5–15, 1924.

[2] H. C. Sherman and H. L. Campbell, *Proc. Nat. Acad. Sci.*, 14: 852–855, 1928; and *Jour. Nutrition*, 2: 415–417, 1930.

itself. Thus in typical cases, such as are illustrated by Fig. 5, the same degree of incipient senility which is reached by normal individuals on Diet A at an age corresponding to about 65 years in the human life is deferred on Diet B to an age corresponding to 75–80 years.

It need hardly be said that on both diets a considerable proportion of individuals, as in human experience, die natural deaths before the attainment of these ages. Naturally also, such nutritional improvements as we are here considering lower the death rates of the young as well as of the middle-aged and old, so that the life expectation at birth is improved even more than is that of the adult.

Effect of "Protective Foods" Recognized

There are evidences of several kinds that in direct human experience this same sort of improvement of food supplies—in general terms, the taking of a larger proportion of the needed calories in the form of what McCollum named "protective foods"—acts to support superior development in children and a greater number of years of "positive" or "buoyant" health in adults. The historical and field evidence collected by McCollum and Simmonds[3] and the clinical data of Langstroth[4] together indicate very clearly that the onset of senility is deferred, or the incidence of the so-called degenerative diseases decreased, when the so-called protective foods are given a more prominent place in the dietary.

The idea of such a shift in the relative proportions in which different foods shall be used is already beginning to spread far beyond the laboratory and the lecture hall. The Secretary of Agriculture writes in an official report: "The goal is optimal nutrition"; the president of the American Medical Association says in his official address that science

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[3] E. V. McCollum and N. Simmonds, "The Newer Knowledge of Nutrition," 4th ed. (Macmillan), 1929.

[4] L. Langstroth, *Jour. Amer. Med. Assoc.*, 93: 1607–1613, 1929.

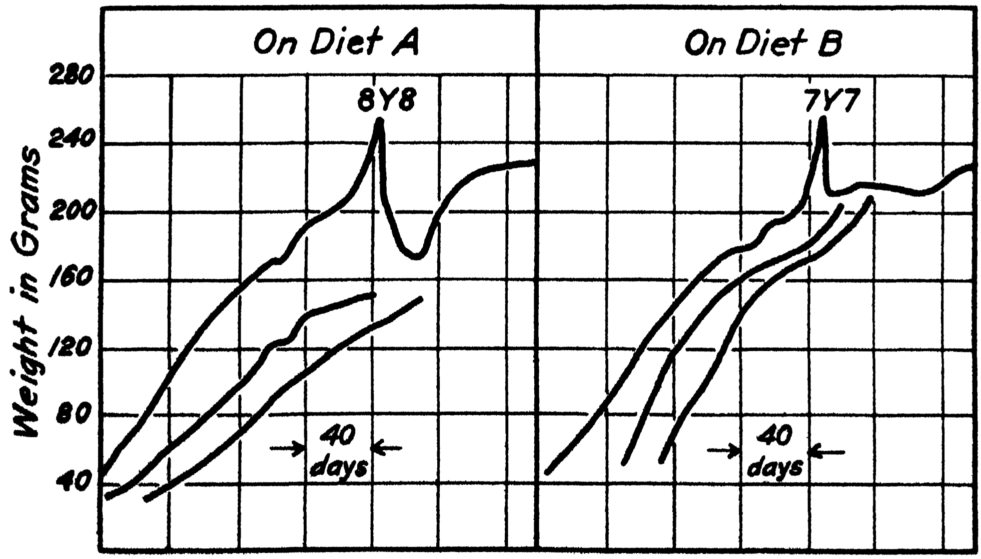

FIG. 4. WEIGHT CURVES.

Typical weight curves for a mother and two of her young on each of two diets. Both mothers reared all their first litters (8Y8 and 7Y7); but on Diet B the mother's body was better maintained, and also the young grew at a better rate.

promises, to those peoples who will use the newer knowledge of nutrition, greater vigor, increased longevity and a higher level of cultural attainment; and the representative of Australia commands the attention of the League of Nations with his slogan, "Marry Agriculture and Health."

Perhaps science will be joined by statesmanship in bringing these recent advances of knowledge into the service of human welfare. In any case, this newer knowledge of nutrition is widely taught in the schools, is at least beginning to be used in a growing proportion of homes; and will (whether rapidly or gradually) become more and more effective through an increasingly informed and intelligent consumer demand.

At the same time, further scientific research can be of great benefit in showing more precisely the possibilities in this field; and developing more fully the ways in which these possibilities can be brought into service with a minimum of encroachment upon, and also with a minimum of retardation by, social customs, individual preferences and economic problems. Many of the economic problems can, in fact, be helped to solution by this new scientific knowledge.

ATTAINMENT OF "BUOYANT HEALTH"

And, so far as we can judge, the positive improvement of health, the induction of a more buoyant health, can be added to the gains in health, efficiency and longevity which are attained in other ways, as through genetics, sanitation of environment and training of mind and body The concept of the nutritional improvement of such health as is already "passable" to a status more "buoyant" (to use the terms of the *Journal* of the American Medical Association) fits excellently the scheme recently offered here at the Institution from the genetic point of view (Fig. 6).

To picture, as an addition to the diagram in which the life cycle is represented by the path of a projectile, the improvement which can be made through nutrition, if we think in terms of *positive* health, is as if the projectile, instead of merely responding passively to its original impetus, were (like a rocket or torpedo) generating additional propulsive power during its flight; or, if we think in terms of the word *buoyant*, it is as if we had found a way of partly offsetting the downward pull of gravitation (of diminishing the rate at which we tend to age), which is essentially what the newer chemistry of nutrition is now doing in finding how to induce and maintain a *superior internal environment.*

Our actual experiments, thus far, are chemical and biological—not psychological—but so far as our minds are domiciled in our bodies it seems reasonable to expect that a superior internal environment may have a more than merely biological value.

At any rate, we may now accept as established, (1) the existence of a wide and evidently fruitful area of research between the merely adequate and the optimal in food supply and nutritional condition, and (2) the general validity of our present methods of animal experimentation in this field of research.

FURTHER INVESTIGATIONS

The further experiments now in progress are designed to extend present knowledge in two main ways. We seek to establish the relationships of the individual chemical factors of food value to the nutritional improvements originally effected by adjustment of the relative proportions of ordinary articles of food. This should make possible such formulation as to facilitate the fullest functioning of these findings both in pure science and in medicine, dietetics, and food economics.

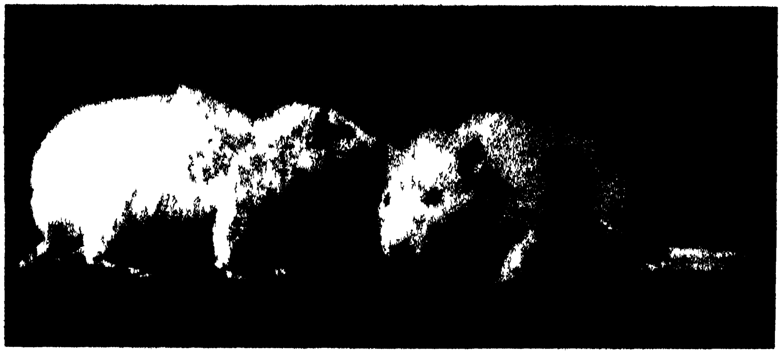

FIG. 5. AGING RATS.

THESE RATS HAVE ALWAYS BEEN HEALTHY AND NORMALLY NOURISHED, BUT WHEN PHOTOGRAPHED WERE BEGINNING TO SHOW AGING (COMPARE WITH THE HEALTHY YOUNG RAT IN FIG. 3). THE EQUAL DEGREE OF INCIPIENT SENILITY IN THE TWO CASES HERE SHOWN WAS REACHED, AS EXPLAINED IN THE TEXT, AT DIFFERENT AGES—ACCORDING AS THE DIETARY HAD BEEN MERELY ADEQUATE OR SOMEWHAT BETTER.

And, simultaneously, we seek also to ascertain just what kinds and degrees of enrichment of the dietary are effective for the nutritional improvement of health at *all* stages of the life cycle. Even during the time that our present (current) experiments have been in progress, this latter question has been given increased prominence by the tendency of certain pediatricians to warn against the assumption that the most rapid early growth is necessarily the most conducive to future well-being, and by the finding in the Agricultural Experiment Station at Cornell that a very rapid growth, induced by extremely rich diet given in unlimited amounts, may not always be best in its effects upon the life cycle as a whole.[5]

There is not necessarily any real conflict between the Cornell and the Columbia findings. If they appear divergent this may be simply because they deal with widely separate areas in what we now see to be a very broad field of investigation.

The starting point of the Cornell experiments was an extremely rich diet, such as may be approached in occasional cases of the forcing of farm animals for maximal gains in body weight; and possibly when an infant is fed without regard to economic considerations and with too great a desire to make a phenomenal record of growth at an early age. Such cases of undue forcing of growth by extreme richness of food, if they actually occur in practice, are doubtless relatively rare; they do not seem likely to affect more than an extremely small minority of the population

The starting point of our experiments at Columbia was a dietary much more representative of the food supplies upon which the great majority of people must depend. The chief sources of food calories are the grain products, here represented by wheat, and the dietary is made adequate by the inclusion of an economical proportion of the so-called "protective" foods, here represented by milk.

FACTORS IN ENRICHMENT OF DIET

Between our Diets A and B the sole difference was the relative proportions in which these everyday foods were consumed. But the change in this single experimental factor means, when the description of the experiment is transposed into chemical terms, the enrichment of the diet in not less than four respects: calcium, protein, and the vitamins A and G.

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[5] C. M. McCay, M. F. Crowell and L. A. Maynard, *Jour. Nutrition*, 10: 63–79, 1935.

We seek now to establish, as rigorously and precisely as possible, the rôle in this connection of each of these four factors, beginning with calcium.

The minimal level of calcium intake for permanent support of normal nutrition appears, from the findings of several investigations, to lie between 0.13 and 0.19 per cent of calcium in the dry food; while the optimal level is materially higher, though just how much higher is a problem still under active investigation.

Both by calcium-balance experiments with growing children[6] and by analyses of the bodies of experimental animals[7,8] it is found that even when there is every appearance of normal growth there may be considerable differences in the rate of calcium retention, depending upon the calcium content of the food.

Such data upon the period of growth and development are, of course, not conclusive as to the *ultimate* effects. But experiments recently completed, which cover the entire life cycle and extend into successive generations, indicate that the diets with moderately increased calcium content, which have expedited growth and development, with earlier attainment of an adult percentage of body calcium, have also induced higher vitality throughout and improved the life expectation of the adult as well as of the young.

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[6] H. C. Sherman and E Hawley, *Jour. Biol. Chem.*, 53 375–399, 1922.

[7] H. C. Sherman and F. L. MacLeod, *Jour. Biol. Chem.*, 74: 429–459, 1925.

[8] H. C. Sherman and L. E. Booher, *Jour Biol. Chem.*, 93: 93–103, 1931.

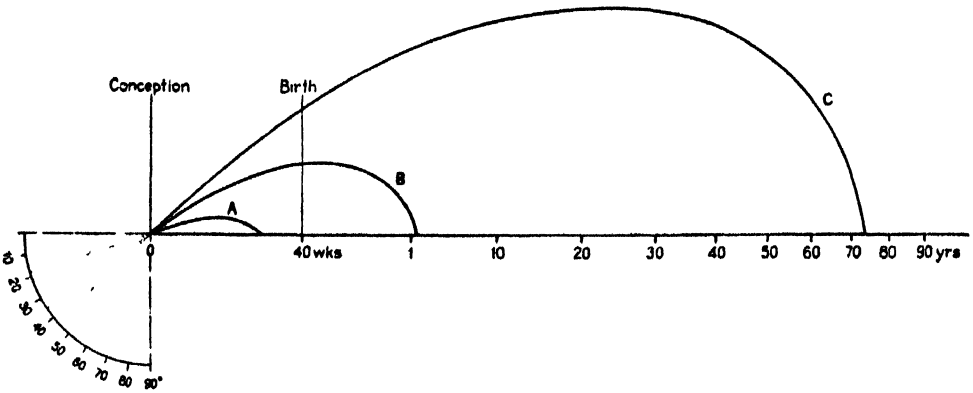

FIG. 6. LIFE AS A BALLISTIC CURVE.

Life is shown as a ballistic curve, the form and span of which are determined by: the initial quality of the egg cell and the resistance it meets in its further course. In the three curves, chosen as typical, it is assumed that these individuals encounter the common wear and tear of existence. The difference in their life-span results entirely from the difference in their initial quality. Were the wear and tear greater or less the curves would be correspondingly altered. In such a diagram the relative initial quality of the egg-cell can be expressed in terms of degrees of the angle of primary inclination. The newer knowledge of nutrition shows how the normal path here pictured becomes both higher and longer when to the initial impetus there is added the sustaining effect of a better-than-merely-adequate dietary with resulting nutritional improvement of the internal environment.

EFFECTS OF INCREASING CALCIUM CONTENT

With all other factors held uniform,[9] this moderate increase in the calcium content of the food has resulted in more rapid growth, more efficient utilization of food value whether computed in terms of calories or of protein, slightly earlier maturity, improvement of the already normal health at all ages, and some increase in the average length of adult life.

In this particular series, the gain in longevity by the males is undoubtedly significant, while that by the females is smaller and if it stood alone would not be statistically convincing. Before one concludes, however, that the nutritional reactions of the sexes are different in this respect, there should be similar experiments comparing the effects of the two food supplies upon the life histories of unmated females and upon groups of families in which the factor of pregnancy and lactation is held constant. For in the experiments just mentioned, the females on the food supply richer in calcium produced and suckled more young and it is conceivable that if the demands of pregnancy and lactation had been less frequent and heavy these females might have lived somewhat longer. It is hoped that opportunity can be found for such an additional series of experiments.

EXPERIMENTS IN PROGRESS

Meanwhile, experiments are already in progress to determine the effects of further enrichment of the diet in its calcium and phosphorus contents,[10] and with and without simultaneous enrichment in protein content, vitamin values, or both.[11] Other work in our laboratory has suggested that both in the case of vitamin A[12] and of vitamin G[13] there is progressive nutritional benefit with increasing liberality of intake up to levels probably at least four-fold higher than the "actual" or minimal needs of normal nutrition.

We hope to continue the studies of the effects of these relatively high levels of intake of calcium, of protein and of vitamins A and G throughout the life cycles of at least two generations.

What level of consumption yields the best results is, therefore, a question whose answer, it now appears, will differ rather widely for different factors of food value.

Of food calories, the level of intake which yields the best results in the long run is very nearly the same as the minimum which will maintain a normal status

Of protein, the optimum is now generally held to be not over twice the normal minimum.

Of calcium, the results thus far obtained seem to indicate that the best results are reached only at a relatively more liberal intake, perhaps about three times the normal minimum.

While with vitamins A and G, the present indications are that the best results may require at least four times as much as would cover the minimal normal needs.

The necessity for brevity prevents the discussion, here, of those aspects of our research which have shown that the growth data of our experiments have such a symmetrical frequency-distribution as to justify a high degree of confidence in their statistical interpretation[14]; and the further finding that faster or slower growth as an *individual* charac-

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[9] H. C. Sherman and H. L. Campbell, *Jour. Nutrition*, 10: 363–371, 1935.

[10] Unpublished experiments of E. W. Toepfer.

[11] Unpublished experiments of R. T. Conner and of L. N. Ellis.

[12] E. L. Batchelder, *Am. Jour. Physiol.*, 109: 430–435, 1934.

[13] H. C. Sherman and L. N. Ellis, *Jour. Biol. Chem.*, 104, 91–97, 1934.

[14] H. C. Sherman and H. L. Campbell, *Proc. Nat. Acad. Sci.*, 20: 413–416, 1934.

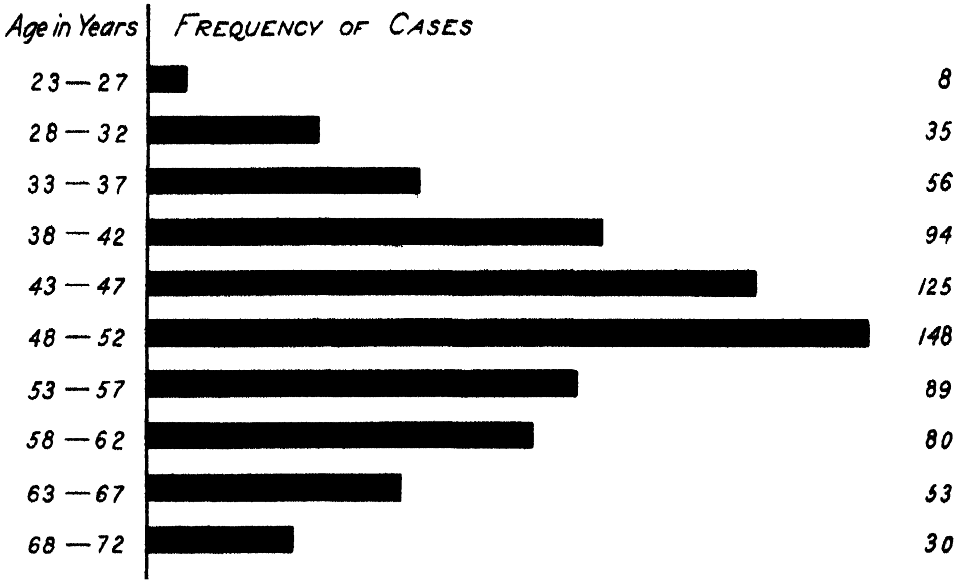

FIG. 7. AGE INCIDENCE OF MAJOR OPPORTUNITY.

FROM DATA DERIVED LARGELY FROM "AMERICAN MEN OF SCIENCE," FIFTH EDITION, THERE IS HERE CHARTED THE INCIDENCE OF MAJOR OPPORTUNITY IN DIFFERENT AGE RANGES, AS EXPLAINED IN THE ACCOMPANYING TEXT.

teristic does not in itself influence the life expectation. That is, the *strictly individual* variations in growth and in longevity are independent, not interdependent.[15]

These two findings place our research program in a much stronger position for the solution of the further problems mentioned above as still under investigation.

While the improvements in health and longevity, to which the newer chemistry of nutrition is showing the way, involve nothing so dramatic biologically as a mutation, or as some of the exploits of endocrinology, yet they seem to have a more than biological significance.

BROADER HUMAN IMPLICATIONS

May we conclude by glancing very briefly at some of their broader, and perhaps more far-reaching, human implications?

In one of his annual reports, commenting upon the deaths of two colleagues, the late President Woodward remarked that a third of a professional or scientific man's years have usually passed by the time he has finished his formal schooling and entered his constructive life work; then probably another third will be spent in proving to himself and to others what he is able to do, before he will be entrusted with his highest responsibilities; and so, only the last third of his years remain in which to render his fullest service to the world.

A recent charting of the age incidence of major opportunities of presumably representative men in occupations of a scientific or related administrative or educational nature, strikingly confirms Woodward's impression that the most frequent time of attaining (or being promoted to) such "fullest" opportunity, is around the age of 50 years. Perhaps equally striking is the wide range of ages at which appreciable numbers of men have actually found (or been admitted to) their major opportunities (Fig. 7).

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[15] H. C. Sherman and H. L. Campbell, *Proc. Nat. Acad. Sci.*, 21: 235–239, 1935.

Both these facts emphasize strongly the advantages to the individual and the gains to society which may confidently be anticipated from the earlier attainment and the longer retention of the full adult capacity and efficiency of individual persons (and of the constantly increasing proportion of people) who will have received the benefits of the newer chemistry of nutrition.

Such improvements should greatly facilitate what is now being found so important both in scientific research and in the industrial world, team work on terms of essential equality between younger and older people, to bring into the service of a given enterprise the full advantages both of the newer training and of the more mature experience, as well as of differing but mutually helpful points of view. And in proportion as work has social value, the value to society of longer individual careers (with full opportunity opened earlier in life and in ways which permit the full use of experience also) should be increasingly recognized.

As President Merriam has pointed out in his essay entitled "Are the Days of Creation Ended?",[16] the direction of human evolution is now largely social, and society is a continuing organism interested in its own future. What promises to affect this future should influence our decisions from day to day and will do so more effectively with the growth of the scientific spirit which expects progress and works for it; but meanwhile the shortness of individual lives tends to set a limit to the actual use by man of the knowledge which he has accumulated and the institutions which he has built and developed. Hence the longer term of fully efficient years which the newer chemistry of nutrition offers may be of far-reaching significance to human progress in affording fuller opportunity for the use and enjoyment of the ever growing body of knowledge.

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[16] J. C. Merriam, "The Living Past" (Scribner's), 1931.

THE INFLUENCE OF SOLAR VARIABILITY ON WEATHER

By Dr. C. G. ABBOT

SECRETARY, SMITHSONIAN INSTITUTION

METEOROLOGISTS with few exceptions have attributed weather changes to the complex make-up of the earth and its atmosphere. Certain observations and statistical studies lead me to believe that an important factor in weather production is the fluctuation of the intensity of the sun's radiation Hitherto no attention has been given to this factor in official forecasting. The following paper indicates the magnitudes of weather changes which solar variability may produce. Whether or not these effects may become readily predictable, their recognition seems to me to be a step in advance.

Viewing the sun as a variable star, its percentage range of variation is not large. Careful measurements made by the Smithsonian Institution at favorable mountain stations in desert lands since 1918 do not disclose a total probable range in the solar constant of radiation of more than 3 per cent. It is quite possible, but not capable of proof as yet, that larger solar changes have occurred in the past and may occur in the future. But this is outside of our present inquiry.

Fig. 1 shows a series of solar constant observations made on every suitable day from June 3 to November 2, 1934, at two stations. Mount Montezuma lies in the southern hemisphere, Lat. 22° 40′ S., Long 68° 56′ W.; Alt., 9,000 feet. Mount St. Katherine lies near Mount Sinai in Egypt, Lat. 28° 27′ N., Long. 34° 0′ E.; Alt., 8,500 feet. Thus the local conditions which might have affected these results included summer at St. Katherine and winter at Montezuma. Yet the average deviation of the daily values, including all which are graded by the observers as satisfactory, S, or nearly satisfactory, S–, is 0.4 per cent. This means that the methods and observations are so satisfactory that results of two stations 7,000 miles apart, one operating in winter, the other in summer, are little affected by instrumental errors and by the variable conditions prevailing in the ocean of atmosphere above them. For assuming that the two stations are equally good, we find their individual average daily probable error in estimating the intensity of solar radiation in free space at the earth's mean solar distance is only $\frac{0.4 \times 0.8}{\sqrt{2}}$ or 0.25 per cent.

To the eye, Fig. 1 seems to indicate several variations of the sun of the order of 1 per cent. But when we compute correlation coefficients from all these data of the two stations which are marked S or S–, the value comes out insignificant. Everybody knows, of course, that such is always the case when a small real variation is associated with relatively large values of probable error. But in this case one other justifiable step may be taken. Certain values may be omitted, not because they spoil the correlation coefficient, but because they lie wild in the series observed at their own station. For instance, consider the following case. The figures given below are in thousandths of a calorie. For completeness read 1.900 plus the values given.

ST. KATHERINE

July ..	21	22	23	24	25	26	27	28	29	30
Values ...	46	43	37	39	45	32	45	44	48	47
Grades ...	S	S	S–	S	S	S–	S–	S–	S–	S–

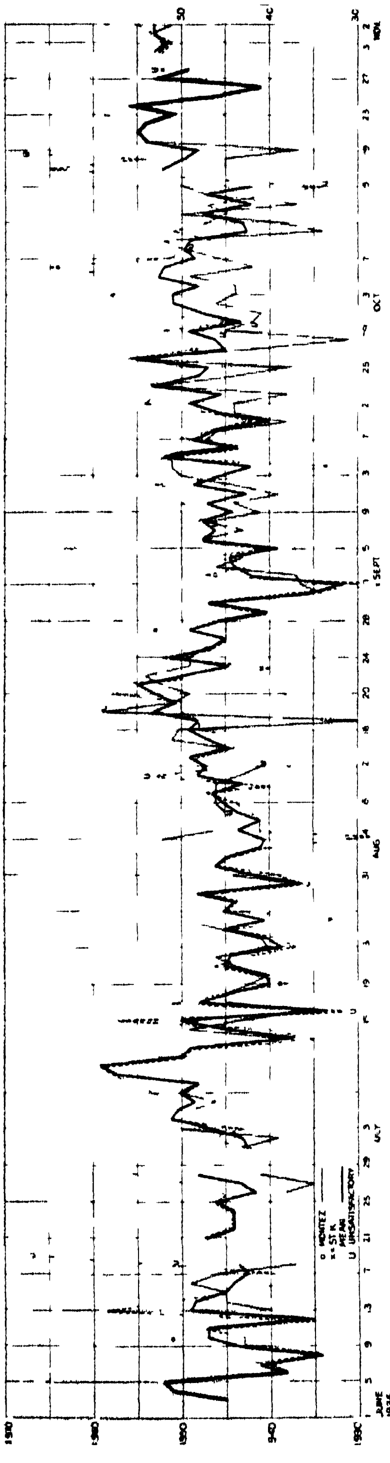
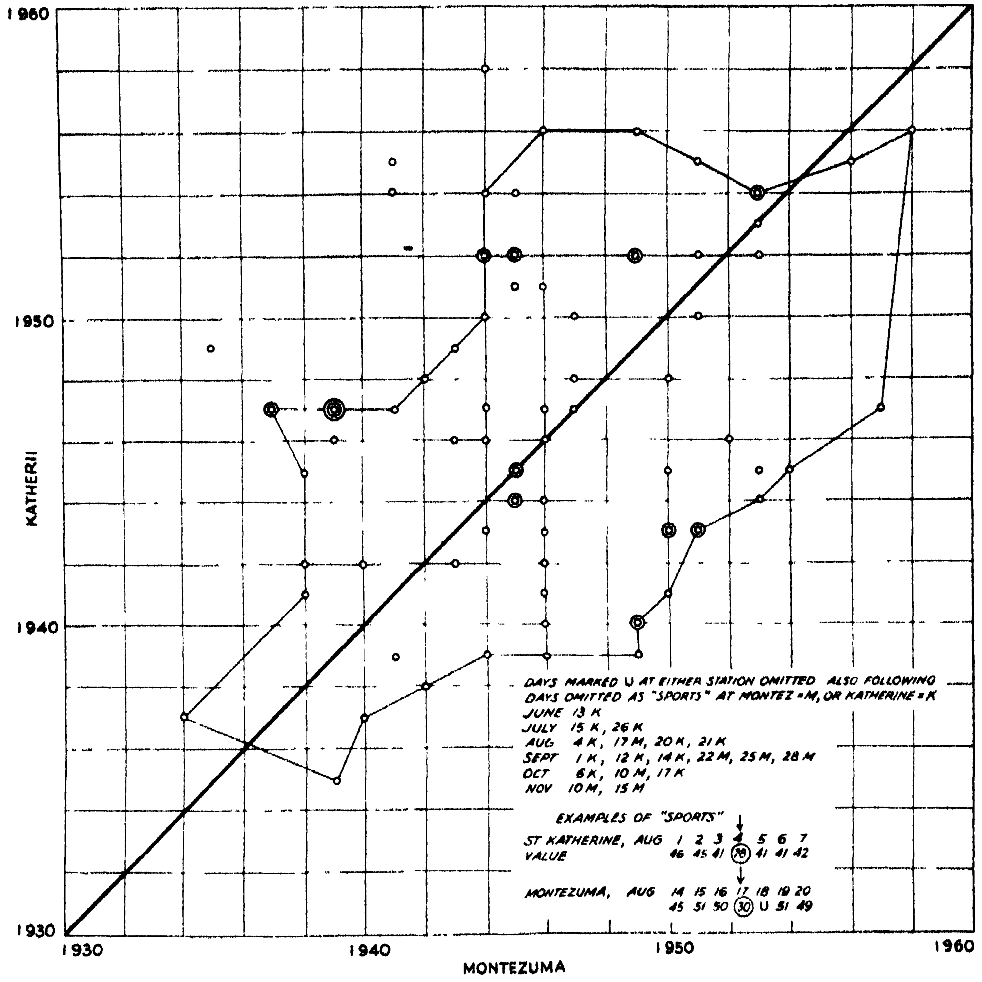


FIG. 1. COMPARISON OF SOLAR CONSTANT VALUES FROM TWO STATIONS 7,000 MILES APART ON OPPOSITE SIDES OF THE EQUATOR. ONE PER CENT. EQUALS FOUR VERTICAL DIVISIONS.

It seems very clear that though to the observers there was little visible objection to the value on July 26, yet it lies so wild compared to its neighboring days that to include it in a correlation computation relating to a possible variation of 0.020 calorie in range it must greatly reduce the resulting correlation coefficient. Acting on this line, Fig 2 represents a spot diagram in which obviously unsatisfactory days have been eliminated in this way, notwithstanding their fair grades as rated by the observers. All the days so eliminated are tabulated in Fig. 2, and the reader may compare them with Fig. 1. As amended, the data show an obvious correlation, confirming our impression that variations of the sun occurred between June 3 and November 2, 1934.

Still the reader may object to what has just been suggested. I therefore undertake another line of argument. Let us assume that the sun really varies at short intervals, as Fig. 1 indicates. Further, let us assume that such solar variations produce sensible weather changes, in temperature, for instance, at Washington. It would naturally follow that whatever the effect might be when the solar constant increases for several days, the opposite temperature effect would follow when the solar constant declines.

With this idea in mind I have sought out *all* the cases occurring between January, 1924, and December, 1930, when sequence of several days indicated rise or fall of solar radiation. The values of the solar constant discussed are those observed at Montezuma, as printed in *Annals, Astrophysical Observatory,* Vol. 5, Table 31. I did not include sporadic single-day jumps but only those occasions when several days indicated a real rising or falling sequence. Nevertheless,



COMPARISON OF SOLAR CONSTANT VALUES JUNE - NOVEMBER, 1934

FIG. 2.

it is highly probable that some of my cases are spurious. Hence the temperature effect caused, if real, is the more unlikely to be found. None of the changes of solar radiation were on their face values large. Their average could not have exceeded one half per cent.

The temperature departures used are the differences between the reported daily means of Washington maximum and minimum and a smooth curve drawn to represent the monthly means of this quantity as published in the first volume of *World Weather Records.* It is not to be supposed that the temperature effects, if real, caused by solar changes would be the same at different seasons of the year. Hence I segregated the results by months, throwing, for example, all cases in which the solar constant showed rising sequences in the months of January between the years 1924 and 1931, inclusive, into one table, and so on.

Fig. 3 shows the actual result of this experiment for the month of April, which is one of the better months, but in no way exceptional. The reader will note the marked opposition of temperature departures at Washington, covering even details following, respectively, rising and falling sequences of solar variation. The spread of temperatures is very large, amounting, respectively, to 12° and 11° F., two days and twelve days after the solar change began which seems to have caused it. All other months show similar oppositions of effect, and many months show as large effects as April.

The actual march of temperature departures in Washington following solar changes alters from month to month. Rising tendencies follow rising solar sequences for the months December to April, inclusive. The opposite is the rule from May to August, inclusive. The other months show well-marked opposition, but in irregular types of march It is, of course, probable that some other classification than a monthly one would be preferable. The type of temperature march doubtless depends on the pattern of the atmospheric circulation by which weather influences of solar origin arrive at Washington. For they immediately affect certain centers of action thousands of miles away, and travel through the atmosphere by roundabout paths. Further study of the phenomena may lead to a better grouping than the monthly one.

Much further investigation of the dependence of temperatures on short-interval solar changes is contemplated. Here it needs only to be added that the later solar constant work since 1930 leads to demonstrations of opposition of temperature effects similar to that of 1924 to 1930. What is certainly extraordinary is the apparent fact that one half per cent. change in the solar constant of radiation may produce 5° to 7° F change in temperature departures, and

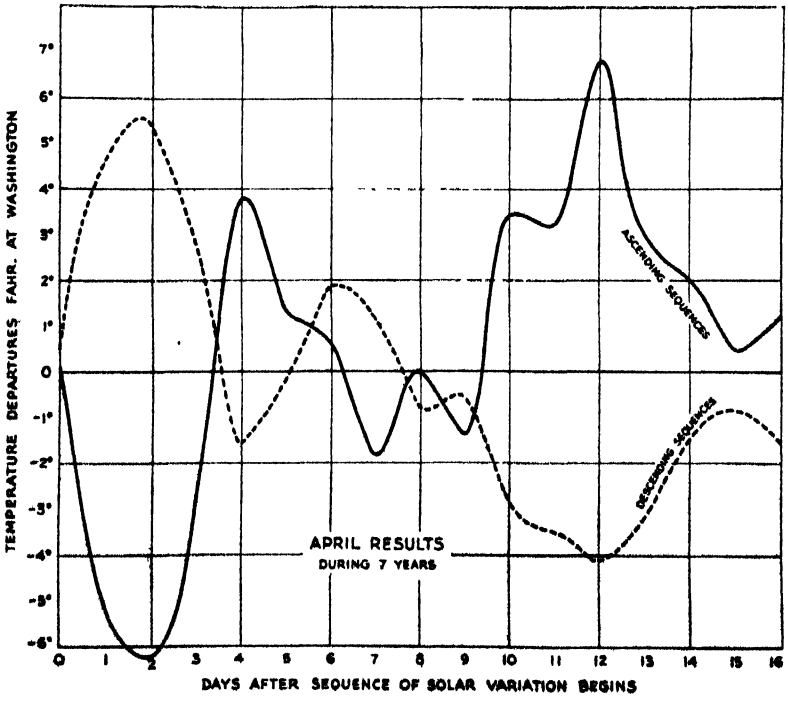


FIG. 8. OPPOSED TEMPERATURE DEPARTURES WHICH FOLLOW RISING AND FALLING SEQUENCES OF SOLAR VARIATION.

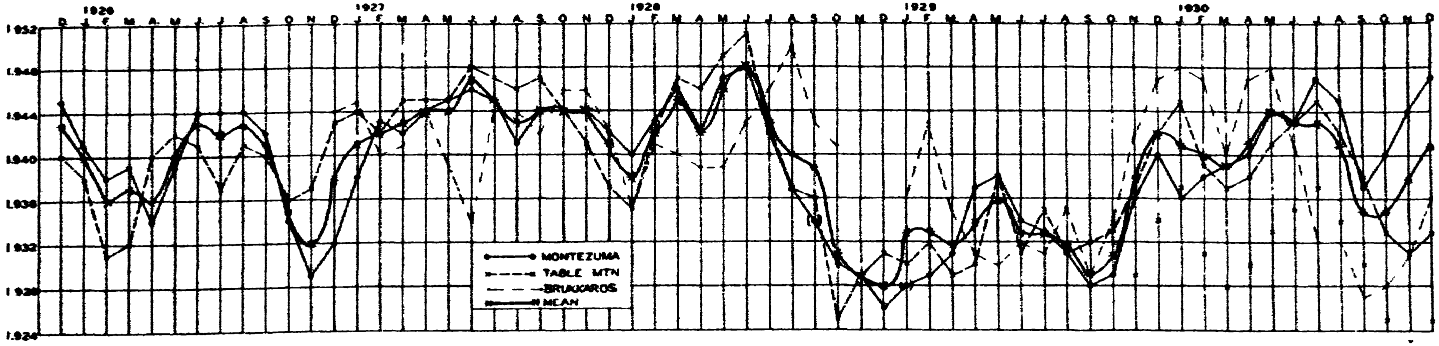


FIG. 4. COMPARATIVE RESULTS OF SOLAR CONSTANT OBSERVING AT THREE WIDELY SEPARATED STATIONS.

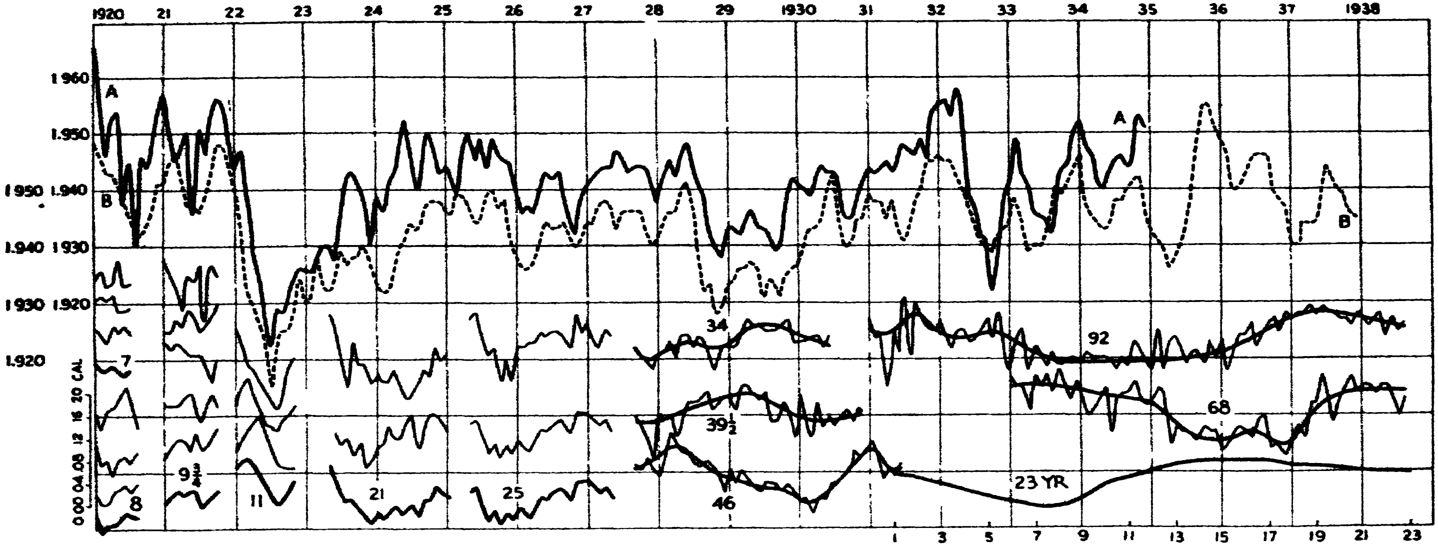


FIG. 5. SOLAR VARIATION, 1920 TO 1934, WITH PERIODICITIES FOUND THEREIN AND THE APPROXIMATE REPRODUCTION OF THE ORIGINAL CURVE BY THEIR SUMMATION.

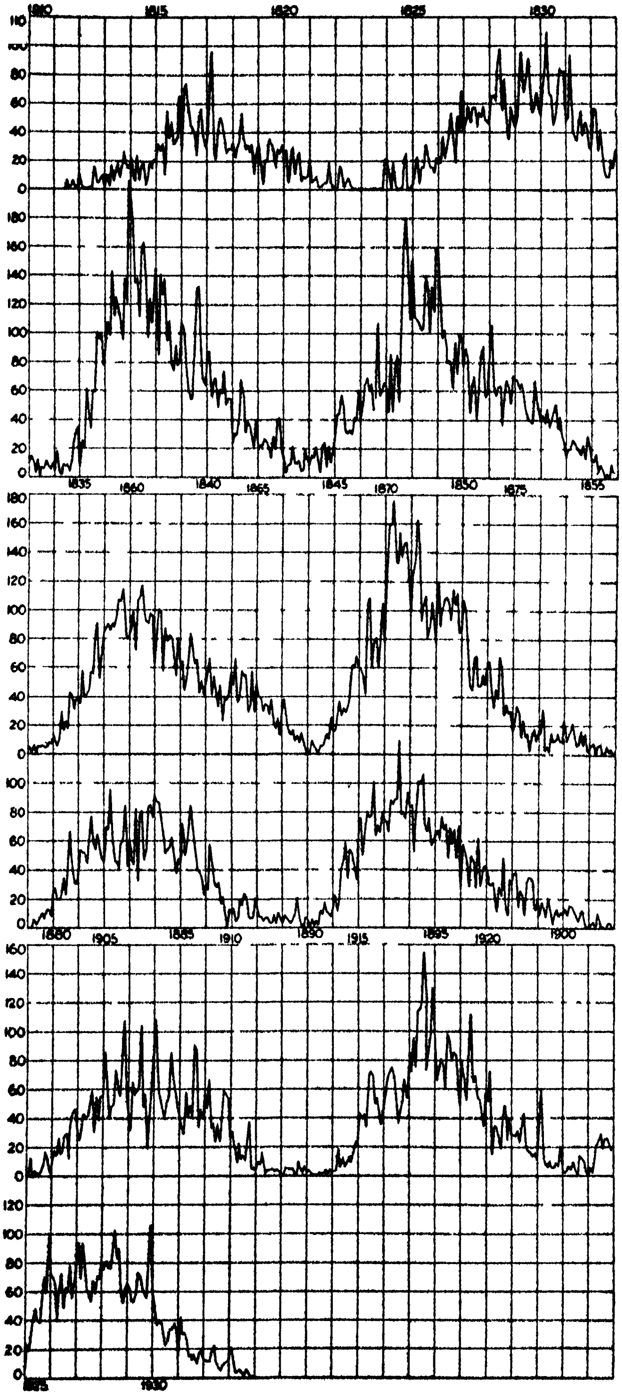


FIG. 6. PERIODICITY OF SUN-SPOTS SINCE 1811. NOTE THE LEFT CURVES ALWAYS SMALLER THAN THE RIGHT, INDICATING A 23-YEAR PERIOD.

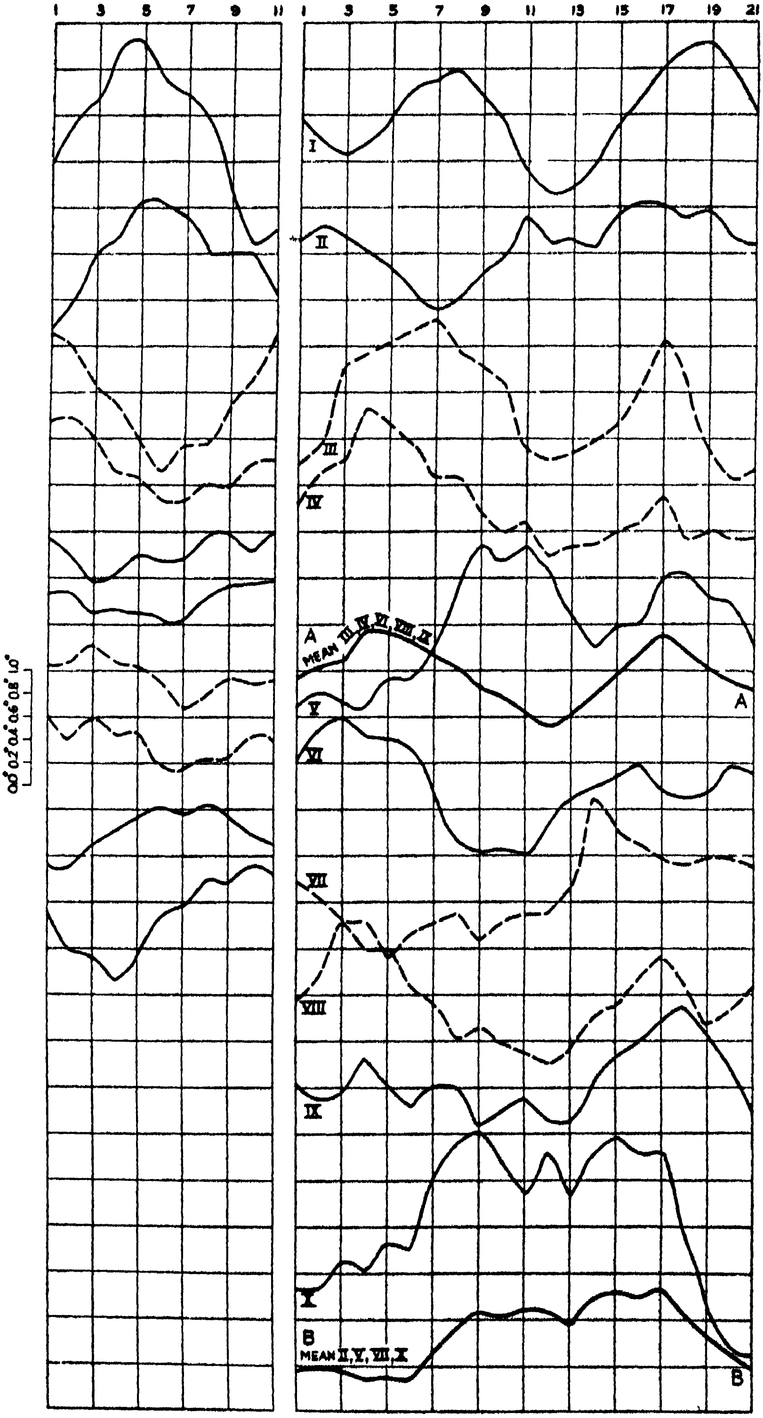


Fig. 7. The 11-month and 21-month periodicities in the temperature of Berlin. Note reversals at multiples of 11½ or of 23 years from 1819.

may extend its influence over a period of two weeks after the solar change begins. I have as yet made no attempts to use this relationship for forecasting.[1]

We now turn to longer intervals. In Fig. 4 is shown the mean monthly march of solar constant values as observed from 1924 to 1930 at Montezuma, Table Mountain and Mount Brukkaros, stations separated by many thousand miles, and in opposite hemispheres. The reader will perceive that though divergences occur, on the whole the three stations afford mutual support. When we reflect upon the small probable error of an individual day's work at such a station as Montezuma, as stated above, and that it is to be divided by $\sqrt{16}$ or thereabouts in a monthly mean, one sees no reasonable doubt that the fluctuations are large enough to prove that the sun did actually vary as shown. Fig. 5, Curve A, gives the best result from 1920 to 1934.

Analysis of the solar variation indicated by Fig. 5 discloses that it may be represented, to an average deviation of one fifth of one per cent., as the summation of the following twelve periodicities: 7, 8, 9¾, 11, 21, 25, 34, 39½, 46, 68, 92 and 276 months. For the shorter of these periods the data may be separated into two or more parts, so as to see if the period holds in form and phase throughout. In Fig. 5, I show such an analysis of the data. The heavy lines give the average form and phase of the twelve periods. Their summation in the dotted curve, B, may be compared with the original data in Curve A. The most interesting thing about this analysis is that it was only after about half of the periodicities had been discovered independently, one by one, that it was noticed that they have an approximate least common multiple in 276 months, or 23 years.

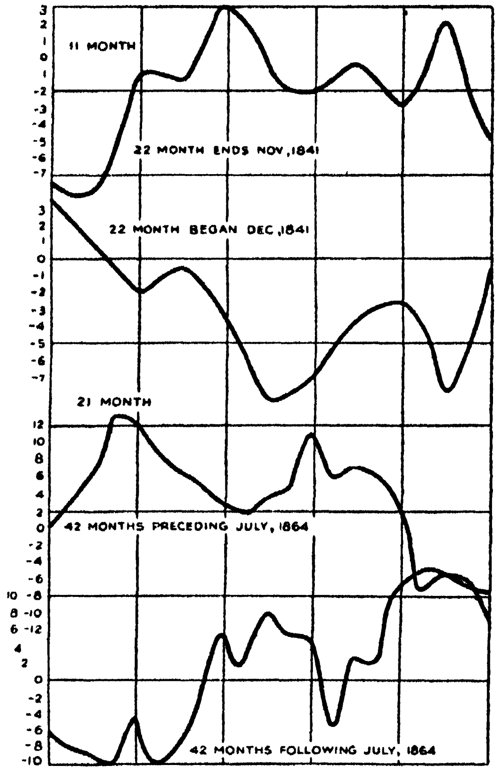


FIG. 8. SHARPNESS OF REVERSALS IN BERLIN TEMPERATURE PERIODICITIES.

Then it was recalled that Hale had discovered that the magnetism of sun-spots shows a complete cycle composed of two 11-year sun-spot periods. Still later I have noticed that the sun-spot cycles themselves have an alternate inequality, and therefore a complete period of two 11-year cycles. This is seen clearly in Fig. 6, where every left-hand curve includes a less area than its right-hand neighbor.

I do not pretend to explain why the sun's radiation displays as periodicities a fundamental and eleven overtones. In the vibrations of a violin string this would not be remarkable, but why it should occur with a sphere of perfect gas I must leave to mathematicians.

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[1] A completer study of these phenomena is about to be published by the Smithsonian Institution.

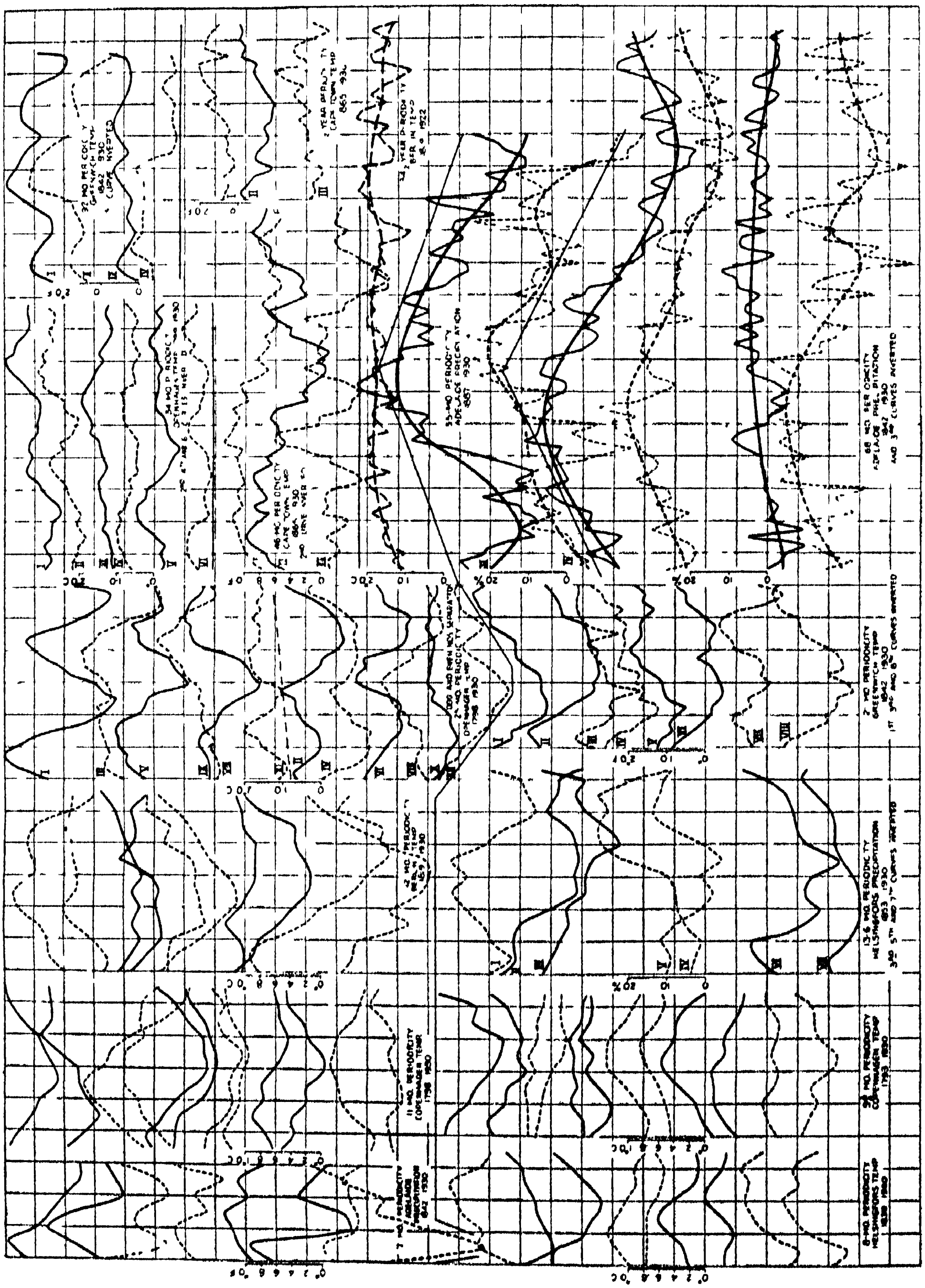

FIG. 9. SAMPLES OF PERIODICITIES IN WEATHER FROM VARIOUS STATIONS. NOTE CONTROL BY 23-YEAR CYCLE.

Similarly, I do not pretend to explain why as indicated in Fig. 3 a sequence of solar change ranging only about one half per cent. should cause a departure from normal temperatures at Washington of 5° to 7° F. I am presenting statistical results in this paper, not theories to account for them. But I should be immensely pleased and relieved if some one of far abler mathematical powers than mine would explain them.

Assuming these twelve long solar periodicities shown in Fig. 5, what if any evidences are there that they affect weather? In this inquiry I have used the data printed in *World Weather Records,* published by the Smithsonian Institution. As monthly values of weather departures from normal fluctuate widely, I have smoothed such departures by consecutive 5-month means. In the use of precipitation, I have expressed it in percentages of normal, thus avoiding the embarrassment of rainy and dry seasons of each year which widely modify absolute values.

Having, then, such smoothed departures from normal, I tabulated them in ways adapted to disclose the periodicities discovered in solar variation. An illustration of such a tabulation may be found by interested readers on page 37 of my former paper.[2]

I found after much tabulation that a very significant relationship obtains. If one takes January, 1819, as the zero date, he finds that the reversals of phase, which hitherto have baffled seekers for weather periodicities, take place sharply at dates separated from January, 1819, by multiples of 11½ years.

Figs. 7 and 8 illustrate this discovery. Fig. 7 shows the 11-month and 21-month periodicities in the temperature departures of Berlin. It will be immediately perceived that the 11-month curves go in pairs, with a marked change of form occurring between each pair and the next. The individual curves of each pair represent 11-year and 12-year averages, respectively. Thus every pair covers 23 years. As for the 21-month curves at the right, they also cover alternately 11 years and 12 years, but their changes of form take place sometimes after 11½ years, sometimes after 23 years, but always at dates related to January, 1819, by intervals which are multiples of 11½ years.[3]

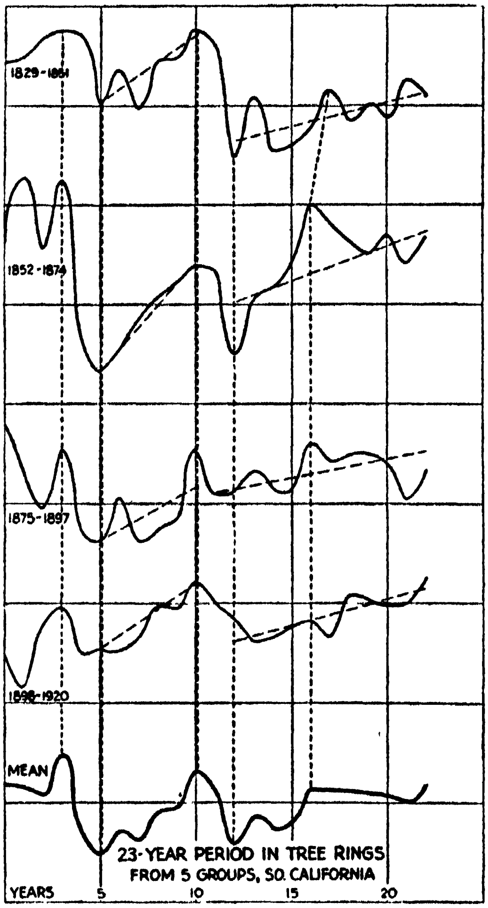

FIG. 10. THE 23-YEAR CYCLE IN DOUGLASS'S TREE-RING WIDTHS.

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[2] *Smithsonian Misc. Coll.*, Vol. 94, No. 10, 1935.

[3] In Fig. 7, A, for "Mean III, IV, VI, VIII, IX" read "Mean I, III, IV, VI, VIII, IX."

Fig. 8 shows how very sharply this relationship with January, 1819, holds. The upper pair of curves represent, respectively, the 11-month period computed from the last 22 months before November, 1841, and from the first 22 months after that date. The lower curve represents the 21-month period computed from 42 months preceding and following, respectively, July, 1864. Both pairs show opposition even in details, and indicate complete reversal of phase at dates sharply 23 and 46 years after 1819.

I submit that the reversals of phase, which at first sight obscure solar periodicities in weather, turn out to be of first-rate evidential quality, confirming the importance of solar variation as a weather factor. It will be clear, however, that, hampered by these reversals of phase, it becomes impossible to determine with satisfactory neatness the forms of the curves representing the effects of the longer solar periodicities on weather phenomena. For however long a weather record is available, it is broken up, as the 11-month and 21-month curves of Fig. 7 show, into successive intervals when the solar influence combined with terrestrial complexity produced different forms of curves representing weather periodicities. This is not fatal to getting good results for shorter periodicities, but leaves us very much embarrassed as regards the longer ones. We lack sufficient repetitions to eliminate accidental and short periodical features from them.

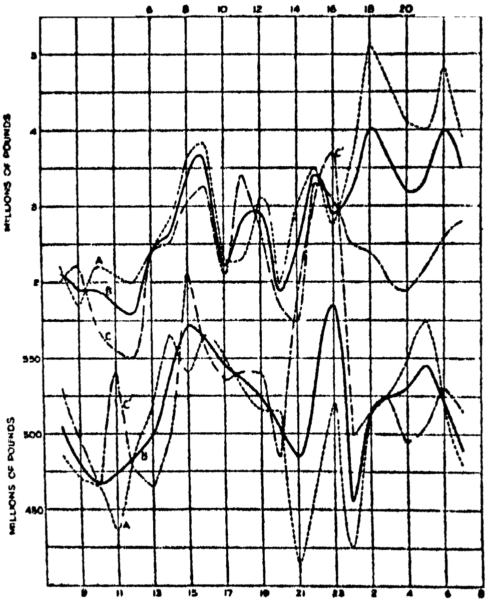

FIG. 11. THE 23-YEAR CYCLE IN FISH CATCHES.

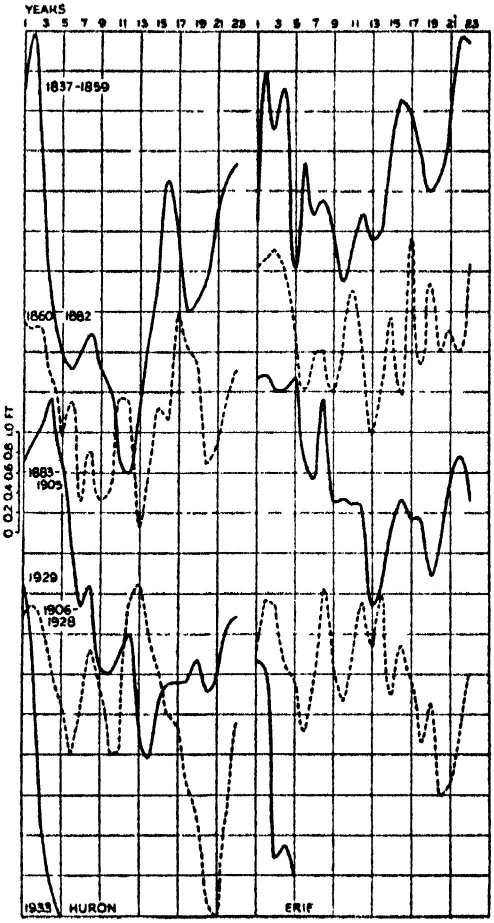

FIG. 12. LEVELS OF GREAT LAKES, 23-YEAR CYCLES. NOTE THE MARKED SUBSIDENCE CULMINATING AFTER 11 YEARS IN THE FULL CURVES, INDICATING DOUBLE CYCLE OF 46 YEARS GOVERNING DROUGHT CONDITIONS.

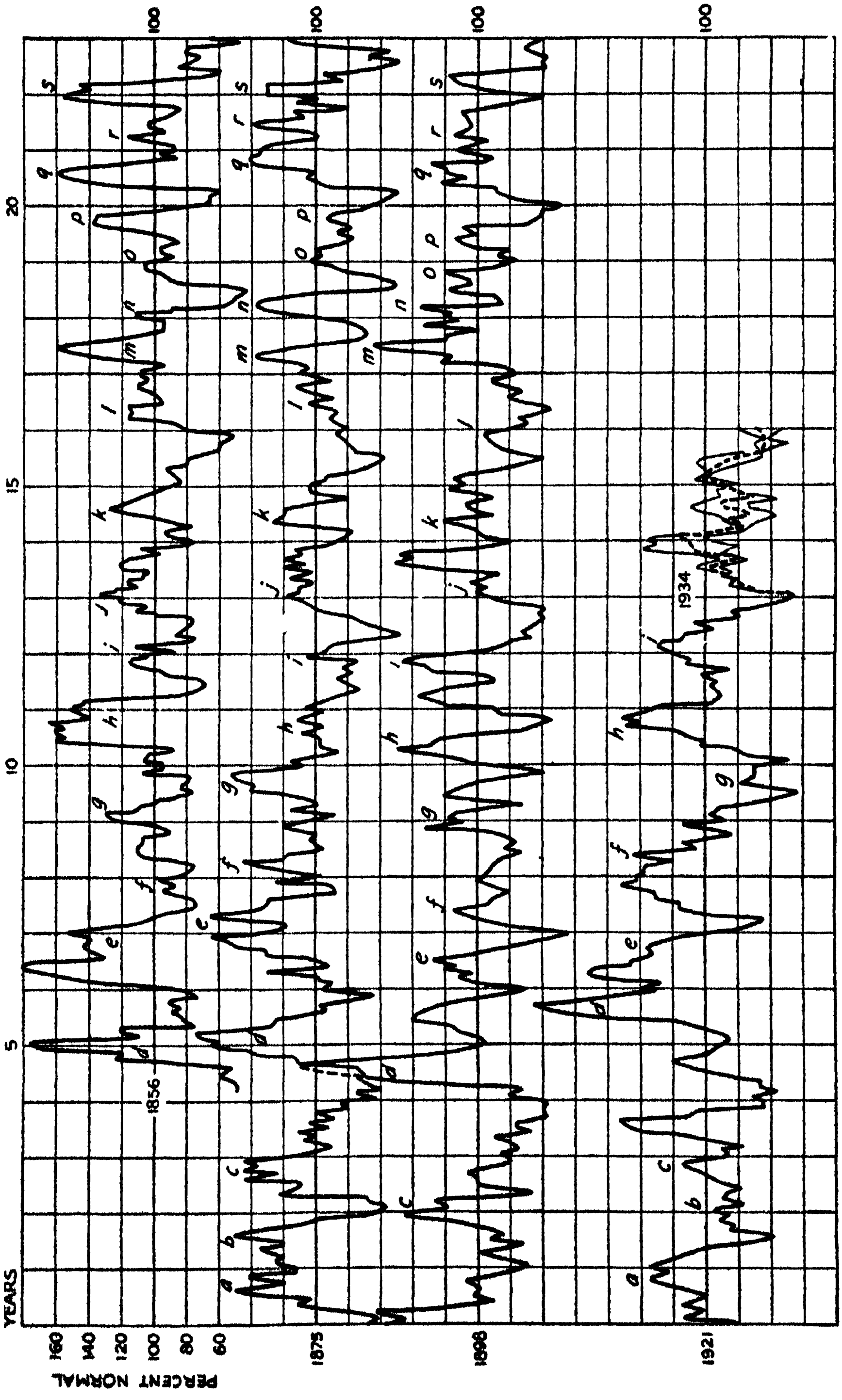

FIG. 13. THE 23-YEAR CYCLE IN THE PRECIPITATION OF PEORIA, ILL. YEARS 1934, 1935 AND 1936 PREDICTED FROM PREVIOUS DATA, AND EXPRESSED BY THE DOTTED CURVE. CORRESPONDING FEATURES IN THE SEVERAL CURVES ARE MARKED BY CORRESPONDING LETTERS.

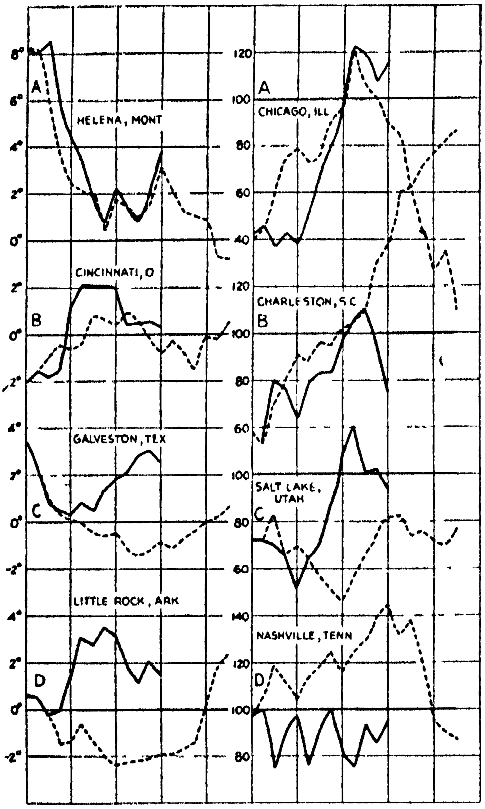

Fig. 14. Sample forecasts and verifications. Dotted curves are forecasts. Grades of results: A, excellent; B, fair; C, half and half; D, bad. Left, temperature; right, precipitation.

With these introductory remarks I refer to Fig. 9, which shows samples of all weather periodicities found, but scattered to represent six stations in different parts of the world, sometimes relating to temperature and sometimes to precipitation in the departures from normal weather investigated. Scales of ordinates are annexed for each group of curves. For the shorter periods, two determinations for each 23 years are given, but for periodicities of 34 months and over, only one. Successive 23-year intervals are distinguished by using alternately full and dotted lines. In order to save space, the successive curves representing the longer periodicities are drawn closer together by inverting those so designated in the legends. There are so many curves shown in Fig. 9 that they may prove bewildering. But I believe the profound changes of form, even amounting to inversions, at intervals of 23 years, are so marked that the reader will not overlook them. See, for instance, the 11-month periodicity of Copenhagen temperatures, the 68-month periodicity in Adelaide precipitation and, strangely enough, as many readers may think, the 12-month periodicity in Berlin temperatures. Everybody would be prepared to find a 12-month periodicity, but who would anticipate that its form would change regularly at 23-year intervals?

We now turn from this branch of the investigation to see how plainly the 23-year cycle and the double cycle of 46 years show themselves in some phenomena which depend on weather. In view of what has been explained we are not to expect sweeping curves of 23-years' interval. Rather, as the subordinate periodicities which the sun's radiation contains impress themselves on weather, numerous features will occur, as the crests and troughs of the periodic solar influences reinforce one another. Owing, however, to the irregularity of behavior of the different periodicities as regards reversal and gross changes of form (see Figs. 7 and 8), the features will sometimes be altered or obliterated or changed somewhat in phase.

Fig. 10 is obtained from data on the widths of tree rings in California, as measured by Douglass in five groups covering the years 1829 to 1920. Many details are seen to repeat themselves in all cycles.

Fig. 11 is a comparison of the 23-year cycles in the catch of cod and mackerel, 1812 to 1931. The values are averaged in alternate 23-year cycles, so as to bring out the 46-year double cycle, if present. But it is not very conspicuous. I would therefore draw attention only to the heavy mean lines, which seem to show that, either directly or through altering the plankton food supply, these two species of fish go through somewhat similar cycles of abundance. The phases occur 2 years later for the cod than for the mackerel. For details of this fish study the reader is referred to the publication above cited.

Fig. 12 shows how marked is the 46-year double cycle in the levels of Lakes Huron and Erie. It is clear that the dry years since 1930 in the Northwest had their prototypes 46 and 92 years earlier.

Fig 13 shows the 5-year consecutively smoothed precipitation of Peoria, Illinois, arranged in cycles of 23 years. Certain features are indicated by letters above the several curves. As remarked above, these features change somewhat in form and phase from cycle to cycle, and yet, I think, remain recognizable. Based on this belief, I ventured to produce on the lowest curve a continuation, which is, in effect, a forecast for 1934, 1935 and 1936. The year 1934 having elapsed, I have compared the event with the prediction, and when April, 1936, comes, so that 5-month consecutive means may be computed, I will do so for 1935.[4] Of 1934, I may merely remark that the prediction for Peoria precipitation falls in the class called "excellent" in the succeeding paragraph, as illustrated for Chicago in Fig. 14.

In Fig. 14, I show four types of agreement which represent the outcome of comparisons of forecasts for 1934 with the events. Curves on the left are for temperatures, and those on the right are for precipitations. The numbers of stations where predictions fell in the several classes are as follows:

Type	Excellent	Fair	Half good	Bad	Total
Temperature	7	17	3	4	31
Precipitation ...	11	11	8	5	35
Total numbers ..	18	28	11	9	66
Per cent. of total	27	42	17	14	100

The experiment is of course so new and startling that I have not felt warranted in disclosing the individual forecasts until several years of testing shall have elapsed. As stated above, the irregular reversals and changes of form in the constituent periodicities must ever render such forecasts based on the 23-year cycle subject to error in phase and amplitude. These may indeed prove to detract ruinously from their value unless it may prove possible to forecast reversals and form changes of all constituent periodicities. But of the thesis that the sun's variation is an important weather factor, hitherto generally unrecognized, I, for one, have no doubt.

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[4] This comparison has been made. It is fairly successful for precipitation, but less so for temperature.

THE SO-CALLED SCIENTIFIC METHOD AND ITS RÔLE AS A PROCESS IN DEMOCRACY

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> In respect to other things there may be times of darkness and times of light; there may be risings, decadences, and revivals. In science there is only progress. . . . What is gained by scientific inquiry is gained forever; it may be added to, it may seem to be covered up, but it can never be taken away.—*Sir Michael Foster.*

THERE have been rather numerous indications in recent years that the contributions of science, or better, of the scientific method, to modern life are not appreciated in many quarters. In this essay it will be shown that the method of science is not a modernized version of the mystical black arts of other times or places, but that it is actually a very ancient and socially secure method of achieving progress that has rather recently been taken over, perfected and named by science.

Not only have the contributions of science not been appreciated, but some have said that the dilemma in which the world finds itself to-day should frankly be blamed on science. These would have us believe that science has destroyed our religion, and therefore our ethics, by casting doubt on the literal accuracy of the story of creation as given in Genesis, and all that is linked with the idea of the literal accuracy of all statements in the Bible and by conquering our material and energy environment so far as to greatly displace human labor with machines and thereby creating technological unemployment. These charges would be serious if true.

But the bad effects of science, we are told, do not stop here. Not only do they say that it robs man of his old-time religion and honest employment for ten to fourteen hours a day, but they also say that it leads him to see himself as a helpless unit in a social order that deals with him in a statistical manner. So many of him are to be rich, so many comfortable, but too many shall perish, and this holds for spiritual as well as intellectual and material riches. All this is said to be controlled by the blind forces of inevitable laws of nature. The angry but approachable God of old, who punished his sinful subjects, is replaced by the impersonal operations of a cold statistical law. Moreover, the blind forces of the society in which we live are said to be the outcome or summation of other blind forces that control our own being. Thus, the will of man is not free, but is under the control of blind neurological and hormonal forces, or drives. How can a man behave himself when his hormones are tormenting him? Can he by taking thought change the quantity of these? Are they not in turn actuated by more primitive but even more blind drives? Finally, we come to the scale of molecules and atoms and these in turn are helpless in the blind fields of energy that fill the universe. It is the helplessness of these that is built up into a helplessness of the nth degree in society as a whole. As long as man was ignorant of the kind of a world he lives in, life was tolerable, because self-deceptions could be sustained, but now that the false façade has been removed by science, nothing of any beauty or value remains.

At our first sight of this hell on earth, we rebel in disbelief or else yield and flow along with the tide. But we shortly discover that neither response is satisfying. The disbeliever, who is attempting to swim against the current, controls his desperate efforts and floats from time to time, and discovers that there seems to be direction to his floating movement. The yielder finds himself attempting to stem the tide at times because he appears to be getting nowhere by passive acceptance. It seems that we are so constituted as neither to be able to yield passively to the universe in which we live nor to stem its relentless flow. But even in this alternation of states we are not free. In the evening of the day or of life, the tendency to float is greater. In the morning of the day or of life, the tendency to swim against the current is greater. So here again a closer view shows this alternation of states itself to be under the influence of another set of inevitable drives.

For those who dwell on a picture of life as thus briefly and incompletely sketched, the whole idea that man can permanently emerge from his present state through any efforts of his own is considered to be highly improbable, if not impossible. Statistically, it is provided that a few individuals shall emerge, but only temporarily. They can not carry the mass along. They are said to be like bright meteors in the dark night, and the darkness following their extinction is worse than it was before. These few can control their spirits, or love their neighbors, or control their lusts, or see a higher destiny for man, but only for a few years or a life-time. After that things fall back to the dead level again. To believe differently, they would say, is to be deluded, to forget the rational implications of man's origin, his nature and his existence. Moreover, they remind us, man's powers at their best are still finite in an infinite universe, and the duration of his life but the tick of a watch in an eternity of time.

All the above and a great deal more is not to be directly or completely disputed, but is it not possible that the picture suggested is a partial or foreshortened one?

However, if we are to dispute implications of the sort considered above, we must broaden our approach. For some of us this is easy. For these the answer is intuitively given, and in some important respects ultra-rational or suprarational. A few, whose spirits respond fully and clearly to great music or poetry, may even smile at the necessity of making a laborious answer, or even at giving serious consideration to such a view-point. To these we freely admit that our rationalistic and materialistic preoccupations may have changed us, but we must also insist that these preoccupations were our task. These achievements in science, that now appear in a disturbing form, have come from the execution of what seemed to be tasks assigned to our time and to our generation. It seems to many of us that we were obliged to do these things; they were our calling in life. But now in the cool of the evening after a period of achievement, we must be permitted to see what we can say to clarify this partial or foreshortened view of the fruits of our labors. As yet we can not see ourselves as Samsons, who have been pulling down the pillars of our own world, and in doing so, inadvertently accomplishing our own suicide.

In this case the historical view is the one that we can best adopt. Science as we know it to-day is the ripening fruit of a long period of growth and preparation. The pessimistic view that we have attempted to represent would lead us to believe that man himself can not achieve permanent progress. Whatever basis for this view may exist in some directions, it is not true in the field of medicine, for instance. Here we surely have obtained progress and improvement. The life of man has been bettered, at least so far as its comforts and duration are concerned.

This has come from stemming the tide, from opposing the flow of the infinite and inevitable forces of destruction inherent in man's own constitution and in the world around him.

My disconsolate friend may object and say that this, too, is under the control of immutable law. We shall not argue the point, because we, too, believe that it is. However, the law that we have in mind is different in that it permits of change. This law works in such a way that if one generation of men can contrive to pass on to another generation the arts that it has inherited and invented, that generation can use these heritages as a basis or springboard for new developments. This law is also unique in another respect, and that is that man seems to be the only living creature that has become the beneficiary of it, within the range of consciousness. Most of the processes taking place in a man, below the level of consciousness, are a heritage from ancestors, passed on to him by a process of inheritance below the level of consciousness. But these arts that we speak of are carried on in consciousness. Man may accept and pursue them or refrain from doing so, at a price. Man is thus seen to be subject to two kinds of inheritance: the one kind, that he has in common with all other creatures, is, comparatively speaking, not under conscious control, and is the more primitive of the two; the other is in some respects under conscious control, and in this man has more freedom. By this I mean that a man in mating can not say just which of the qualities that he and his mate can transmit shall appear in the child that is to be born, but that the child that is born can in some important degree determine whether a strong linguistic or mathematical bent shall be expressed and developed, if at all, in one way or another.

Considered from this standpoint, the whole known history of man is the record of his attitude toward this law. The oldest known culture of the Stone Age man, for instance, was transmitted in this way. The only method of transmission was imitation. Stone age boys played with implements of their own manufacture, as much like those of Stone Age fathers as possible. The continuity of Stone Age culture depended on a continuity of education by example. The development and improvement of language helped in this transmission because the example could be accompanied by an oral commentary, and so technical education was born. Although the process was thus improved, the effective transfer still depended on the reception of these cultural heritages by suitable pupils, as transmitted by suitable teachers. Any break in this flow caused a break in the continuity of the culture. Eventually, greater continuity was achieved in Egypt and some other places by the invention of writing, and so some of the records were reduced to a more impersonal and permanent form. Moreover, these ancient people became so enthusiastic about the new methods of preserving their records that they often literally covered their public buildings with them. They had found a way to a new kind of immortality, and at the same time an escape from one of the hazards of history—the break in the flow of pupils and teachers.

But the process of keeping such records was laborious. Stones were heavy and hard to cut; clay tablets were awkward if too numerous and easily mislaid; paper was scarce and perishable. There was a struggle among these materials and the verdict went to paper and ink. Because of its perishability, preservation now depended on preserving and recopying the frayed copy. For this labor much leisure and a certain amount of wealth to defray the costs were required.

Too often these were not available, and the pressures of other interests relegated these books to closets and attics, where they no doubt frequently became nest-building material for contemporary mice, as happens so often to our own literary heritages.

However, with the invention of printing, the number of books could be greatly increased. Likewise, the standard of wealth required to possess books was thus reduced. Moreover, books could be written and printed in the vernacular, and so we find the books of Martin Luther the "best sellers," in the first century of the printing press in Germany, find them read by many peasants, and find them translated and circulated in other countries Not only had the continuity of transmission been improved, but the stream of knowledge was now greatly broadened and deepened, and for propaganda purposes the written word could now replace the spoken word. Men suitably placed spent years in study and thought and recorded their progress in books that were given to the printer instead of to the copyist So it was in the sixteenth century.

In the seventeenth century in England a group of thinkers and experimenters, who appear to have called themselves the "Invisible College," hit upon the idea of recording in writing, and then in print, individual steps in advance in their individual fields of interest, and of publishing this material as the *Proceedings* of their society, which by this time was called the Royal Society. In some other countries the same or a similar idea was worked out about the same time. Thus the modern so-called scientific paper came into existence.

This was a clever utilization of an opportunity by which the lag in the transmission of knowledge and ideas from one receptive mind to the other was diminished. Moreover, vast amounts of time could now be saved by the diminution of the duplication of effort. Moreover, missing facts and ideas could be obtained from the perusal of these progress reports, which we call scientific papers.

Of course, all these developments accelerated progress, but it must not be thought that these were the most important factors in the progress itself. They were essentially outward expressions of a corresponding inward change in man himself. This change was essentially merely an improvement in the utilization of his mind, in wrestling with his own limitations and the forces of the world in which he lived. He had somehow obtained an excellent brain and now he was learning to use it. He had not only learned how to save and transmit his arts and crafts from one generation to the other, but he had learned how to spread the benefits over much of the population, *i.e.*, had democratized them. Whereas before these higher cults had of necessity been reserved to the privileged few, they were now accessible to the many. Although the aristocracy of learning was breaking down, the world as a whole was richer for it.

Even so, this highly perfected technique for maintaining the continuity of transmission of culture, and for spreading the opportunity of achieving a knowledge of the heritage of the past, sometimes failed to function, or in any case breaks in the continuity occurred. Nearly every one knows such instances, and they must have been more numerous in antiquity. Just one instance of this sort may be cited as an illustration. The early members of the Royal Society, and Robert Boyle especially, worked with the gas oxygen in such an intimate way that it seems incomprehensible that they should not have discovered it, and yet its discovery was delayed 100 years longer. It is true that its eventual discovery arose from the continuing influence of the writings of Boyle on the development of chemistry, but it did not come directly out of these early experiments on combustion and respiration, as it seems that it should have. Such breaks in the continuity of transmission and therefore of progress still occur too frequently.

Our digression to this subject of the transmission of cultural achievements was made in order to show by a simple example how man has learned to capture, preserve and transmit experience. Our digression showed us that he has done this by adding the inventions of new generations to the achievements of his ancestors. We traced the process far enough in the field of communication to see how these arts have continued to grow and develop. At each stage the received knowledge was sifted, sorted, edited and organized for the new age. This reworking naturally led to the discovery of lacunae and opportunities for improvements. By the investment of great pains and patience man learned how in some respects to stem the tide of the infinite and inevitable extinction of separate and individual achievements. The life of an individual could now be more than merely the biological transmission of life to a new generation. By this method man as a race could lift himself to heights of mastery over his environment, that are high above anything that the average man as an individual could achieve by his own strength in his own lifetime.

In this connection it is interesting to note that man has developed institutions as fast as needed, whose special purpose is the preservation and transmission of this inherited and newly acquired knowledge and skill. Among the most important of these are the schools of all degrees. How well or how badly these institutions have fulfilled their function at various times and in various directions is not to be considered here: they are the most effective device that society has as yet contrived for this purpose.

This, then, as we have seen above, is the method of science: the sifting, sorting, editing, organizing and appraising of the cultural heritage by which simplification and clarification is achieved and at the same time inaccuracies and imperfections are revealed. This method provides work for every sort and degree of worker, including the gifted and luminary genius. The scientific method is, therefore, a democratic process, as distinguished from the more purely intuitive method of the isolated genius, who gains his following by the force of his own personality and intellect, *i.e.*, by his genuine aristocracy. The latter method depended on the power of a personality and the enduring loyalty of disciples. It has given the world great things in many times and places, but almost as many great things have been lost or corrupted because of the failings of disciples who lacked the genius and insight of the initiator. There can be no question that from the standpoint of individual achievement the latter method has furnished very great examples, perhaps greater than the former, but the rich fruits of modern science have been largely gained by the aid of similar giants working within the boundaries of the scientific method. We need to mention only Copernicus, Newton and Darwin as examples; men of outstanding beauty of character and democracy of spirit.

Of course, it may be objected that this accretional process is not the method of science. Such considerations are based on the idea that this method was created within the field of science, for its own special purposes, as a program for the conquest of our material and energy environment. It is true that it did become this eventually in the days of Galileo or thereabouts and that the idea in this form then rapidly spread from the field of physics to that of physiology, chemistry, etc., but it had had a long history before Galileo.

The method of science in this modern form is the purposeful marriage of skilled hands and skilled minds, and this marriage had been consummated even in antiquity. The great civilization of Babylon seems to have been the fruit of a great technology of hydraulic engineering and irrigation. That of Egypt was achieved in geographic isolation because of the opportunity presented by the Nile valley. Imhotep was grand vizier, high priest, chief physician and chief architect of King Zoser. He it was who designed and built the first great pyramid. Here we have technical and theoretical skill of the highest degree combined in the same individual, and it is no accident of history that through Greek contacts he has been preserved to us as one of the two traditional semi-deities of medicine. The Greeks, however, for some reason did not take over this practical aspect of Egyptian culture so fully. They therefore did not properly appreciate their own Archimedes, who was no doubt their greatest scientist. This aspect of science faded out still more as Greek culture was transmitted to Rome.

In fact, it seems to have been separated gradually into philosophy on the one hand and the crafts on the other, although there undoubtedly were always some men who represented both. Thus we see Leonardo da Vinci looming up as a master craftsman and as a prophetic scientist in an age when Galileo and his discoveries were still undreamed of.

The above is enough to indicate that the method of modern science is really merely the adaptation of an ancient method to a limited set of problems that come within the boundaries of what is traditionally called science and that the method does not suffer from the limitations imposed upon it by that terminology, either in its history or in its possible applications to other problems in our day.

In order to see more clearly how powerful this method of patient and painful accretion is, let us go back about a hundred years in the history of medicine. At this time medicine had enjoyed a series of great triumphs. It had early in the sixteenth century broken the bonds of classical tradition and studied anatomy for itself. It had incorporated with itself, in the time of Harvey, the dynamic conceptions of physics and in this way made its anatomy over into physiology. It had become dissatisfied with traditional therapy and through Paracelsus filed a protest, which later gave rise to chemistry, and eventually all the riches that this approach has given to medicine. The microscope even in its crude form was taken over by medicine and was developed into a powerful tool.

At this time, namely, a century ago, medicine was fresh from such great advances, and in the midst of developing new ones. A naive questioner at this time might have asked whether, in view of all these things, the great scourges of man—typhus, typhoid and yellow fevers, smallpox, bubonic plague, diphtheria and the horrors of famine, for instance—could ever be controlled. Even the most optimistic would have hesitated to say that these and the rest could be placed under control in a hundred years. More likely he would have fallen back on pious statements and have declared that these and other calamities pursue man because of his sinful ways, and could only be removed in so short a time by divine intervention on behalf of a better race of men.

But the hundred years have passed, and we may look at the picture. The microscope gave unbelievable advances; the cell doctrine came out of it, and all that it led to. In short, an overwhelming advance in many directions ensued. The new chemistry grew and gave undreamed-of knowledge to medicine—an advance as great or greater than that achieved by the microscope. Continual reappraisal of values and concepts occurred all along the line. All the scourges named and a good many others were conquered. An infinity of knowledge of overwhelming bulk had been gained and mastered, sorted and organized, by adding together the labors of a few fruitful and inspired hours of a number of gifted workers, and the routine toil of thousands of less gifted workers, in the temple of knowledge.

There is, however, another rather astounding aspect to this story of medical advance, and that is that once it had been learned how to control these scourges, the benefits were to be applied to all the members of the population. Here it was realized that the privileged and enlightened members of society could only enjoy security as long as they successfully spread the benefits of their privileges and enlightenment over the entire social group. Thus it was realized that security lay in democracy and was to be obtained in no other way. It is true that the wealthy aristocrat could isolate himself and obtain moderate security, but complete security could only be obtained by spreading the benefits of the new conquests to the entire group. The history of this side of the question and the implications to be derived from it would require a volume.

There is a story in the Old Testament that Jacob "wrestled with the Lord," and we wonder what he wrestled about, and to what effect. The above story recorded in so brief a way is an account of a modern wrestling with the Lord, to good effect. We have seen how with time the wrestling has improved and the score on the side of man is mounting day by day.

If we may now return to our introduction, the statements made there appear in a new light. All the controls and limitations of action visualized there exist, and yet man has found a way of circumventing them. He has found a way of escaping the limitations set by the shortness of his life, the feebleness of his strength, the smallness of his mind and the brevity of his memory. These limitations appear to be "rules of the game" and there is nothing to be gained by lamenting them. Since the rules as laid down for man's biological existence can not be changed, he has circumvented them. He has escaped by subdividing the job, *i.e.*, by specialization of a sort and by perfecting a technique for recording and transmitting experience. With these two tricks he has gone far toward changing his life on earth. He has not changed the mode of entry and of exit—these are parts of the lamentable rules, so far as we know as yet—but he has greatly changed the conditions of his existence.

Now we used the above example from the history of medicine with a purpose. Man has really done better in this direction than in any other in developing an organized social technique for escaping the implications of his own limitations. The results obtained represented the synthesis of many contributing factors from a variety of view-points in the minds of men, that could control their fears of the unknown and by cool mastery of the facts bring order and safety out of a chaos of fear. Medical men are eventually made of the same stuff as the rest of us, and so the lesson is clear. If by taking thought these men could have done these great things with their own

puny hands and their own infinitesimal brains, we can by the same process and equipment get other results that we want, when we want them long enough and consistently enough to heap up the strivings of hundreds of thousands of men, into one great heap for the accomplishment of our goal. The story that we have viewed shows us that by this same scientific method we can learn to love our neighbors, control our lusts and learn to look up to our destiny instead of down to our animal origin.

The game of life is played according to very strict rules, only part of which are known to the players, and which greatly limit play. However, it must be remembered that rules of play promote skill and resourcefulness. Moreover, this capacity for skill and resourcefulness is just as much a part of our innate constitution as the attributes upon which our disconsolate friend has allowed himself to dwell.

Considered in this way, then, the scientific method is a safe and powerful process in democracy. It is safe because it is a process for overcoming ignorance and error and because it has provided itself with a continuity of transmission of achievements. It is powerful because it has contrived a way to organize and unify the individual strivings of generation after generation of men toward the attainment of a set goal.

If, as has been suggested by some, man were to discard this creation of his own spirit, he would be discarding the greatest thing that he has made. Of course, it is clear that a method so powerful for good may be badly used. Man, at his best, even in the use of this method is a blunderer. He learns as much or more by his failures as by his successes. No doubt we will need to retrace our steps in some directions and to strike out in new paths. But the permanent and enduring successes will be obtained by this method. In the meantime, while these mills of God grind their grist, we must accept such vision and select such leadership as seems best suited to the time and occasion, and we shall not know to the point of certainty, until the grist has been ground, whether we chose wisely or foolishly.

IN QUEST OF GORILLAS

X. CAMEROON FOLKS

By Dr. **WILLIAM KING GREGORY**

CURATOR OF COMPARATIVE ANATOMY AND OF ICHTHYOLOGY, AMERICAN MUSEUM OF NATURAL HISTORY, PROFESSOR OF PALEONTOLOGY, COLUMBIA UNIVERSITY

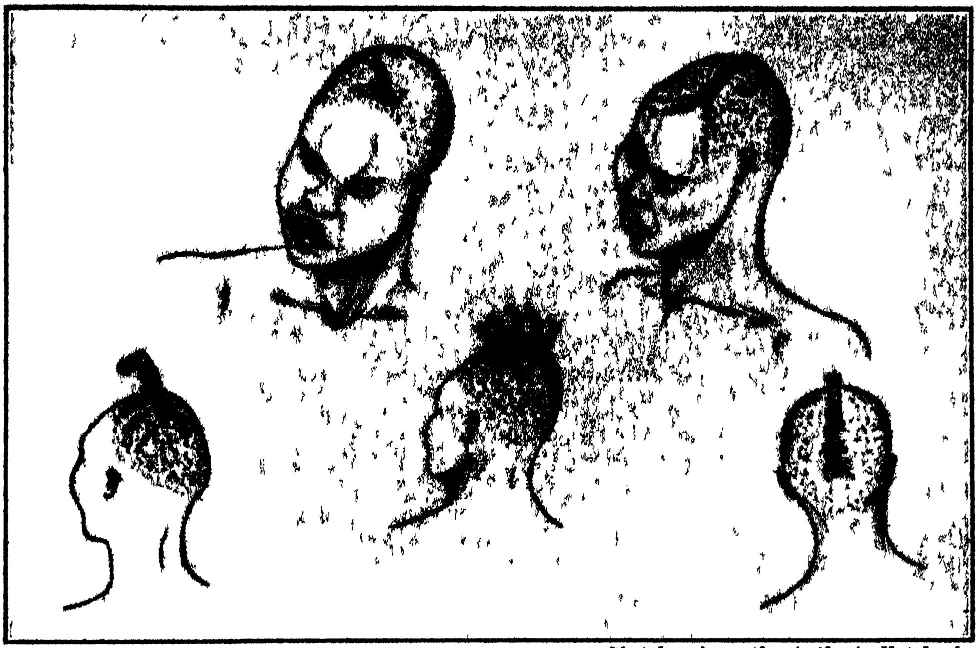
AT Matadi (November 12) the Belgian customs officials refunded the greater part of the money deposited on entering the Belgian Congo and we went on board the French steamer *L'Amérique*, bound for Bordeaux and due to stop at many ports on the west coast of Africa. Our destination was Douala, the port of the French Cameroon.

Then began a most interesting four-day trip, first down the long fiord of the Lower Congo and then northwestward along the coast, stopping at a number of towns on the way. The deck passengers were mostly a lot of natives from the interior, who were being taken up the coast to work on a government railroad. Their outstanding feature was the topknot on the crown of their shaven heads, which they had trained in a variety of comical ways, one projecting like a curved horn, another like a crown, a third like a branched horn, etc. When these men were disembarked they were picked up, eight or ten at a time, in a great rope net with their wives and baggage, swung over the side of the vessel and lowered into a large open boat. As the sea was rather rough, there were some curious scenes as each succeeding net-ful of people was dumped down on top of the earlier ones; but the whole operation was quickly and skilfully done and no one lost his good humor.

None of the various towns at which we stopped along the coast has a good harbor, and passengers and cargo have to be transferred to small boats. There is a heavy surf on the wide sloping beach, and the country as a whole is a flat coastal plain. To avoid the dangers of surf-landing, long steel piers are built out in some towns, high above even large waves, and passengers and goods are hoisted to and from the tenders which go out to the ships. In some places the blacks who propel the small boats jab the water with short paddles that end below in a wide three-lobed shovel and look somewhat like ducks' feet in action One town (Port Gentil) exports an enormous amount of huge logs from the forest up-river, and we were surprised to see here great numbers of fast motor-boats that run up and down the river.

By no means the least interesting sights were the native lady friends of the resident white men. In wide contrast to these chattering birds of gay plumage was a French lady, a bona-fide passenger on our steamer. Although somewhat short, her features were statuesque, even commanding, and from her flashing eye gleamed instant wit, high courage and keen intelligence. Somehow she seemed to belong in a scene of the storming of the Bastille.

After a pleasant four-day trip along the coast we were transferred to a smaller boat that took us up the long estuary to Douala, the seaport of the French Cameroon. Meanwhile we had passed the mountain on the island of Fernando Po, with its summit wrapped in rain clouds. Here an enormous amount of rain falls during the rainy season. According to official reports, in 1913 at ninety-eight stations in this district a



—*Sketches from the Author's Notebook*

ASSORTED TOP-KNOTS

rainfall of no less than eleven meters (35 feet, 9 inches) was revealed for that year. At Douala in 1912 the rainfall reached 4.625 m. (about 15 feet) in two hundred and four days of rain, but this may have been an exceptionally high record The rainfall is much less in the interior Fortunately we arrived in Douala (November 7) near the end of the rainy season and by the time we reached Yaoundé in the interior we had dry weather most of the time.

Douala is quite a flourishing city, with a gay social life. The fashionable hotel is apparently an affair of cardboard and plaster, with leaky roof and little or no water in the faucets. It has a motion picture annex in which one can see American films five years old The streets swarm with native Africans of assorted mixtures, among whom, if we had but known how to distinguish them, we might have recognized occasional representatives of the redoubtable Fans and other invaders from the north, who in times past stewed and ate the peaceful Bantus of the forest.

The city has fine city parks teeming with African trees and fruit-bats From the high plaza opposite the harbor one sees the towering Mt. Cameroon, 13,500 feet high, and on one side low flats upon which mud-skippers (*Periophthalmus*) may be found among the mangroves. The fish fauna in the market is chiefly marine, but in a brook near the market boys were catching snake-headed fish (*Ophiocephalus*), in which the head and the color-pattern are strongly suggestive of a snake

From Douala we went by rail to Yaoundé, a day's journey eastward, to the seat of the Governor-General, M. Marchand. On this railroad journey we found ourselves in the westward extension of the Congo forest. We went upgrade into low mountains composed of schistose rocks and over an extremely high railroad bridge spanning a deep valley; this bridge and indeed the railroad itself had been built by the Germans during their occupation of the territory before the world war. The building of such railroads in tropical Africa has frequently cost heavily in terms of the lives of the Negro laborers, who, after being brought from long distances in practical slavery, have been crowded together along the narrow track and have been weakened by forced labor, insufficient food and extremely insanitary conditions, so that they proved to be easy prey to contagious diseases and epidemics.

A section of the road had recently been washed out by the heavy rains and we had to get out and walk over a long stretch of mud and sharp rocks for perhaps a fifth of a mile to reach a waiting train in front of us. All our luggage had to be carried on the heads of porters, and we appreciated the courtesy of the railroad officials, who had allowed us to ship our baggage over the road in spite of the interruption of service. At another break in the road, requiring transfer of ourselves and baggage, a slight comic relief was afforded by the black trainboy, who placed upside down a short flight of wooden steps which was intended to facilitate our descent from the high floor of the baggage car in which we had been riding. His mistake was quickly noted by the white train conductor, who

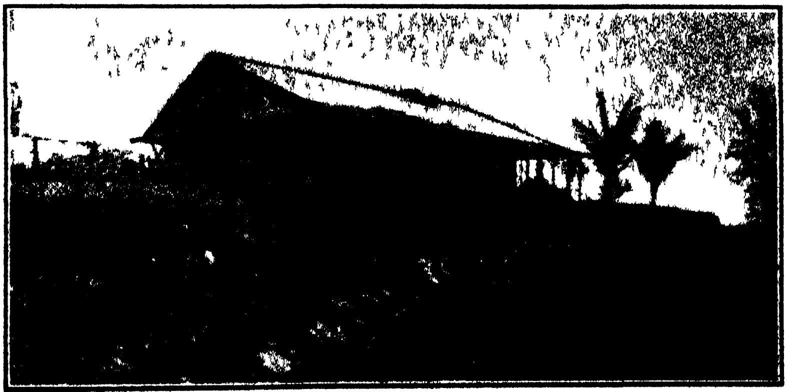
SERPENT-HEADED AFRICAN RIVER FISHES

AFTER NICHOLS AND GRISCOM, FROM COLOR DRAWINGS BY JAMES CHAPIN. *Upper figure:* THE "SPINY-FINNED EEL" (*Mastacembelus*). *Middle figure:* SNAKE-HEAD (*Ophiocephalus*). *Lower figure: Polypterus*, THE "LIVING FOSSIL." RELATIVES OF *Mastacembelus* ARE FOUND IN SOUTHERN ASIA; *Ophiocephalus* HAS RELATIVES IN INDIA AND THE FAR EAST, FROM WHENCE THE FRESH-WATER FISH FAUNA OF AFRICA MAY HAVE BEEN DERIVED; *Polypterus*, ALONG WITH ITS ELONGATE RELATIVE *Calamoichthys* IS FOUND ONLY IN THE CONGO BASIN AND ADJACENT STREAMS; IT MAY BE A DESCENDANT OF ONE OF THE FISHES OF THE TRIASSIC LAKE CONGO. ALL THREE TYPES HAVE ACCESSORY BREATHING ORGANS IN ADDITION TO THEIR GILLS.

—*Photograph by the author*

A QUIET GAME OF JACKSTRAWS

MISSION BOYS AT YAOUNDÉ.

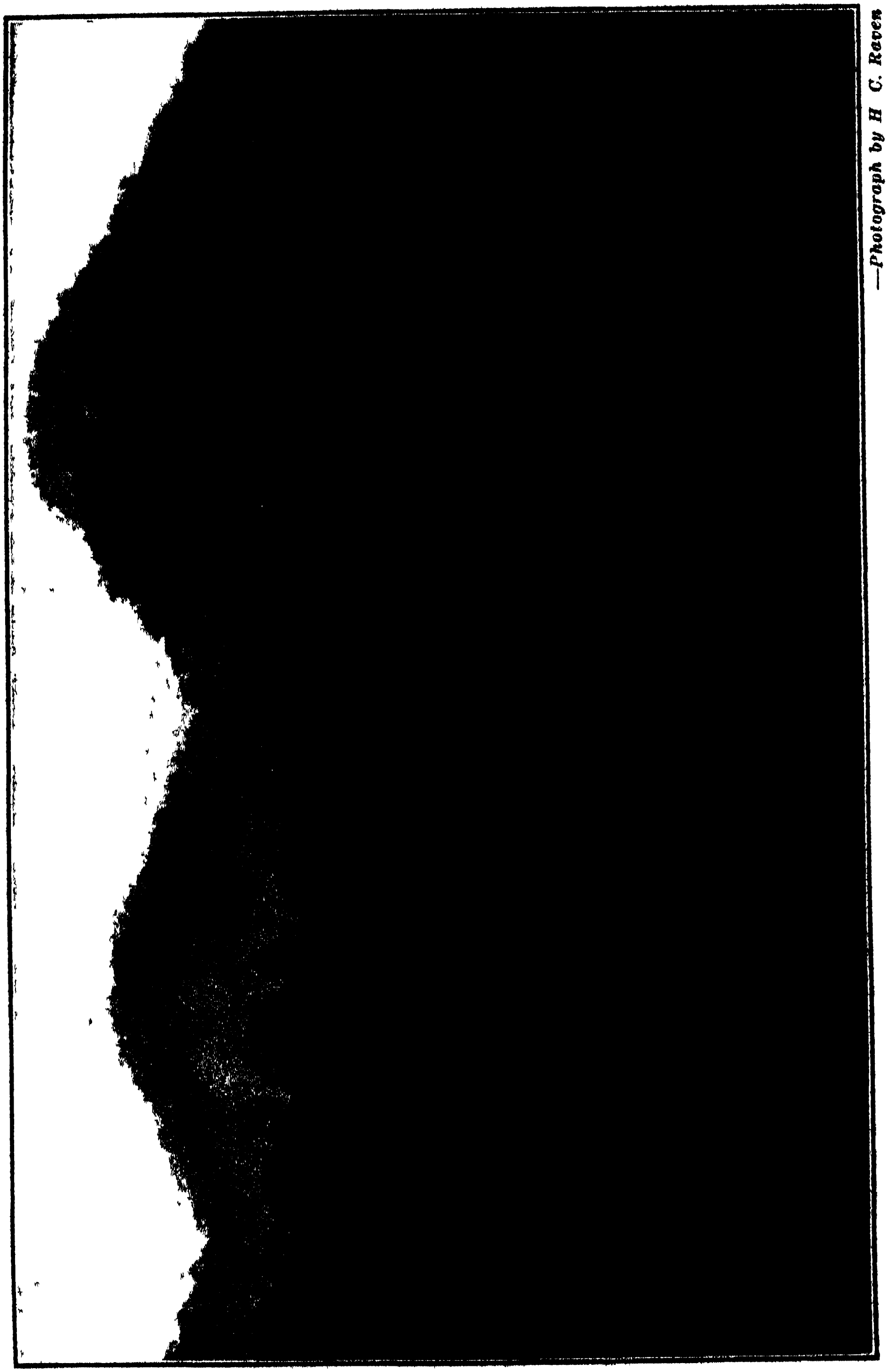


—*Photograph by J H McGregor*

RESIDENCE OF THE HEAD OF THE PRESBYTERIAN MISSION AT YAOUNDÉ

kicked the poor black while emitting quite a lot of abusive language This was in line with the frequent tendency of low-class whites to abuse the blacks, although the higher officials and the government itself tries to protect them against this abuse.

At last we reached Yaoundé, on the evening of Armistice Day, November 11, 1929. There is a fine new hotel building here, but it was not yet open and we had to go to a restaurant and dance pavilion for our supper and lodging. There was only one room available and unfortunately just outside our door a full-sized military band in uniform was providing the music for the Armistice Day Ball. It was interesting to note the absolutely correct rhythm of these blacks, who were playing old-fashioned dance tunes, but as the walls of our room were made of thin boards the volume of the music was terrific, especially as the ball kept up until perhaps 3 A.M. There were two dancing floors on different levels, the upper one for whites and the lower one for blacks, the bandstand and our room being located between them. Neverthe-



—Photograph by H C. Raven

HILLS NEAR OZOUM

—*Photograph by J H McGregor*

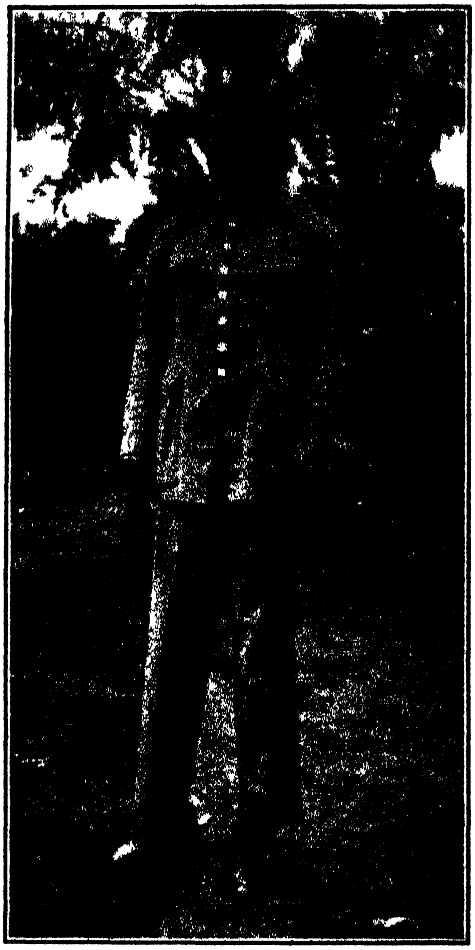
THE PLAZA AT OZOUM

less, we were able to sleep, at least after the ball.

The next day we paid a visit to the American Protestant Mission at Yaoundé and were delighted to receive an invitation from Mrs. Johnston to stay at the mission and make it our official headquarters during our entire stay in the country. The mission includes a fine large church in brown or buff-colored brick, a number of school buildings and a very pleasant residence looking out over a valley toward the mountains. Under the benign influences of the mission the people round about seem to live in peace and contentment. Although ordinary hymn tunes, as sung in America, are sometimes whining and droning caricatures of music, those sung by the black men at the early morning service at the mission were charged with the strange magic which Negroes seem almost always to impart to vocal music.

The mountains around Yaoundé appear to be of metamorphic rocks and are low but rather steep and hump-like.

When we paid our official visit to secure our hunting permit, Governor-General Marchand received us most courteously and after learning the purpose of our expedition, granted us a permit to secure three gorillas and three chimpanzees. He also considered very carefully with us the relative advantages and disadvantages of various localities where gorillas were known to be more or less



—*Photograph by J H McGregor*
CHIEF MARTIN ATANGANA

abundant, and he referred us for additional information to M. Canari and other government officials. It was finally decided that we should try first the district centering around the village of Ozoum, about fifteen miles northwest of Yaoundé, where gorillas had been reported recently. An official message was dispatched to Chief Martin Atangana of Ozoum, requesting him to furnish men for us and to assist us in every way. Accordingly, two days later we departed by camion in the direction of the village of Ozoum, and at a small village where the path to Ozoum joined the automobile road we left the camion and proceeded on foot up the mountain path, under the guidance of Chief Martin Atangana, his brother and their men.

Here then we were at last in the interior of a West African country and within the range of the classic gorilla of Paul du Chaillu. The rainy season was about over and the whole country was beautiful, with low humped mountains covered with forest or jungle. Most of the forest, however, was of the second growth type and there had been a great deal of cutting, clearing and planting. The population seemed very numerous and one wondered how there could be many gorillas in such a country. The people did not differ much in appearance from the Bantu peoples we had been seeing on the Lower Congo River. The villages were essentially similar also, although the houses were now made almost exclusively from the oil palms; these trees were excessively numerous, bordering the automobile roads and dominating in many other places.

As we went up the mountain path we came into some very beautiful stretches of forest with enormous trees, on some of which the leaves had turned red. Except in these small patches of forest, which were rapidly being cut down, villages of low huts straggled along the path all the way of our hour's walk from the automobile road up to the village of Ozoum. There was very little to be seen in the way of either household goods or live stock. The women were probably out working in the "gardens," which looked like jungle to us. The hard mud on the paths, by alternate wetting and drying, had taken on a polygonal pattern somewhat suggestive of basalt columns but on a minute scale.

When we arrived at Ozoum, Chief Martin Atangana conducted us to his very comfortable house and placed at our disposal two large rooms for our dining room and bedroom. Our three new boys,

—*Photograph by H C Raven*

TURN-VEREIN TRICKS

—*Photograph by J. H. McGregor*

SOME OF MY BOY SITTERS

whom we had engaged at the mission in Yaoundé, soon proved their ability by setting up our cots, unrolling our bed-rolls and quickly getting lunch. The chief's house was at one end of the rectangular village plaza, opposite the Catholic church at the other end. The houses of the leading citizens were on either side of the plaza and behind the houses were "gardens," chiefly of banana plants. Low hump-like mountains were to the northwest and the forest to the southeast.

—*Photograph by J. H. McGregor*

NUMBER ONE NURSE BOY

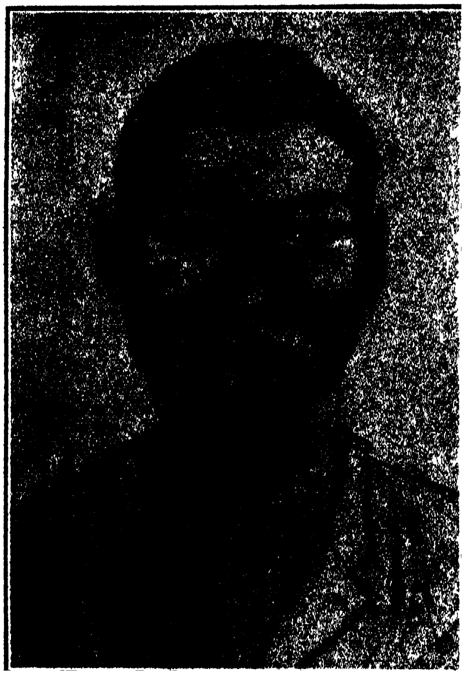
McGregor and I remained at Chief Martin's house for several weeks, while he and his men accompanied Raven in the hunts for gorillas. There were several bands within ten miles of Ozoum, and Raven and his black assistants pursued them with the greatest persistence for many days at a time and through very rough, mountainous country. At night they would stop at some native village, Raven's boys setting up his cot and unrolling his bed-roll in the house of the chief. At times Raven would send back a messenger to get something from us at the base camp; and twice he came back himself to rest for a day before starting out in another direction.

He found that the roving bands of gorillas were highly elusive and almost impossible to overtake. At one place they had raided a banana plantation, tearing down the banana plants and breaking the stout stems to get at the pith. He arrived at this place early in the morning, less than an hour after the gorillas had been there, but after following the band the whole day, up hill and down dale, he had not overtaken them at sundown. At one place the natives had caught a young gorilla in a snare set for a wild pig. They heard the screams of the young animal and hastened down there with their spears. When they arrived they found the "father," as they said, trying to pull the young one out of the snare; but the adult became frightened by the uproar of the natives and went off, abandoning the little one to its fate. The natives cut off its head and hands with their machetes and just before Raven arrived had killed it. Raven told them that if they had kept the young one alive, they might have sold it for a thousand francs. He brought back the head of this specimen and preserved it for our collection.

The native chiefs were willing to undertake a grand drive and slaughter of the gorillas, partly in revenge for the damage done to their plantations, but Raven of course would not authorize or take part in such a procedure. In preparation for such a drive the natives would spread many nets in certain places and try to drive the gorillas toward the nets. They could then spear and hack the animals while the unhappy creatures were struggling to disentangle themselves

The eating of men being out of date, the natives find the gorilla a good substitute, and a certain "white hunter" in Douala told us that he had often been employed by the government to kill elephants and gorillas as food for the blacks that work on the railroad. From Raven's experience in this and other places in the interior of the French Cameroon, he concluded, however, that perhaps ten times as many gorillas are killed by the natives themselves as are killed by white men.

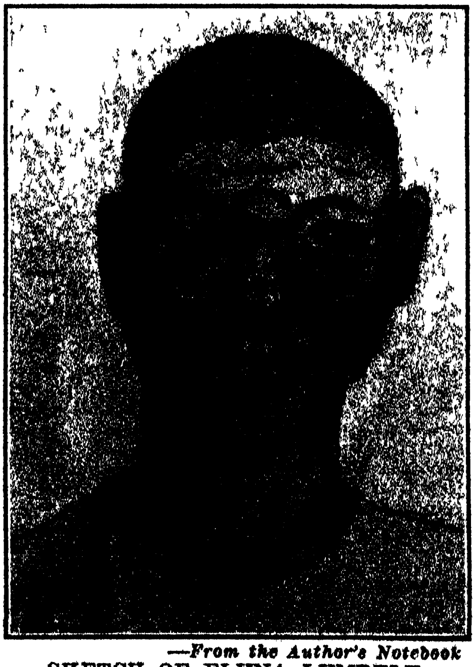
Meanwhile McGregor and I had been having a great opportunity to become well acquainted with the people of the neighborhood, and McGregor secured a large series of cinema and still photographs of them. There we were again impressed by the wide range of variability, both in physical appearance and in disposition of our dark-skinned friends. Chief Martin Atangana was a tall, well-proportioned man, with large eyes and a full beard. In general beards seemed better developed in this region than in the Kivu district, possibly owing to admixture of the forest Negro stock with invaders from the north. Like many of the older people, Chief Martin could remember the time when the Germans came into the country and he had been taught to speak German well in the German Catholic schools. He was a sincere and consistent Catholic, not only



From the Author's Notebook

SKETCH OF PETULIS

THE FEATURES ARE PROBABLY ALL SOMEWHAT TOO LARGE AND THE CHIN TOO SMALL.



—From the Author's Notebook

SKETCH OF ELUNA LUMBELE

reading a German devotional book aloud every day but cooperating with the present French priest in maintaining the discipline of the church in the village.

Not a few of the men of the village were tall, stately and heavily muscled, like some of the fishermen at Stanleyville. Many had massive skulls with a median elevation and a flattened area on either side of it (scaphocephalic type). The nose was usually very broad at the base and there was often a bony bridge above the nose and between the eyebrows. The mouth was large with protruding lower lip and cupid's-bow upper lip. But along with these and other conspicuous negroid features there was an immense range of individual variability. Some men, for instance, had more or less mongoloid eyes, with a perfectly developed "Mongolian fold" covering the inner corner of the eye. Wherever it occurs the presence of this feature in adults is due to the retention of a character that is normal to mankind in general during foetal life but which usually disappears before birth in whites. The presence of this feature in Negroes is probably no sign of admixture with mongoloid elements The face as a whole also varied, one man having the grave lineaments of a statesman, another the comic face of a clown, while a third was just a lethargic peasant.

We did not have the opportunity to study the features of nearly so many women as men, for the reason that in general the women had to work in the gardens every day and also fetch the water, do the cooking and other household work (or what there was of it), so that the men could absorb the proper number of sun-units each day and settle the affairs of state in generous palavers in front of the chief's house.

Our greatest opportunity, however, was to become acquainted with the numerous children of the village. The evening of the day that we arrived the little boys began to perform for us on the open plaza in front of the chief's house. Some hopped like kangaroos, others did elementary "turn-verein" stunts, which might perhaps be reminiscent of tricks taught to their grandfathers by the Germans

A very charming feature of African villages in general was that the little boys were permitted to play about in the plaza and enjoy themselves without repression from their elders. Neither the heathen nor the Catholic Negroes showed a suggestion of the dour medieval Puritan view-point that children must be lashed and bullied into the way of salvation. Doubtless the initiation rites of the heathen blacks in many districts have been horribly cruel, but so far as I could see, the young boys and girls in the Kivu mountains, in the Congo forest and here in the French Cameroon, were free to play and frisk about whenever they were not in school or carrying the baby.

We possessed a number of articles that soon made our house a center for the children of the vicinity. McGregor had brought with him a pair of trick spectacles, to which were attached large "googly" eyes that would jiggle in a comical way when the wearer shook his head. All the small boys and a good many of the men enjoyed trying these on and making the others laugh. Then the children never tired of looking through our field-glasses, although most of them preferred to look through the wrong end, which gave a reduced but very sharp image of the boys near by. On dark nights we let the children look along and above the tube of our flashlights at the eyes of the sheep in the plaza. Such delighted "Eeeees!" and "AH KEHs" as each one caught the dazzling green flash from one pair of eyes after another! The men and women were just as eager and friendly as the children. McGregor

—*Photograph by J. H. McGregor*

THREE LITTLE MAIDS FROM SCHOOL

NGA HEADS THE LINE.

would sometimes cut out little paper figures of sheep, horses and goats and color them with crayons and these were much sought after.

But perhaps the most unfailing amusement was that of crowding around and looking over my shoulder as I struggled to record in my notebook a sketch of some boy or girl who was sitting more or less patiently in front of me. When the onlookers got too boisterous I would suddenly wheel around and hiss at them in a stage whisper, "Hush! keep quiet!" at the same time raising both hands and fluttering them in the manner of an orchestra leader trying to signal for a *pianissimo*. This would start much ill-suppressed merriment and several of the boys would repeat the gesture, hissing "CHIP KYATT" with great emphasis. Nevertheless, they knew what was wanted and would indeed quiet down and move away from my chair—for a few minutes. And what an opportunity that would have been for a real portrait artist, who could have made five portraits while I was struggling with one.

How vividly the individuality of each of my sitters impressed itself upon me as I strained my eyes and brain to catch his elusive personality as his features changed faster than the reflections of clouds in moving water. There was Barucha, a most docile and placid little

—*Photograph by J. H. McGregor*

A CONTRAST

NGA IS STRONGLY PROGNATHOUS, WHILE HER FRIEND HAS A STRAIGHT FACE. OUR HOUSE IS SEEN IN THE BACKGROUND.

savage of pure Negro type. There was Détus Ogmba, a broad-faced little rascal with dancing eyes. "You gee mee monee," he would say. "I gee you CRACK" I would say, hitting my own head with my knuckles, a gesture which he would imitate with monkey-like fidelity. But Détus was full of understanding and sympathy. He knew that I wanted him to sit still and so would hold the pose far longer than any other sitter.

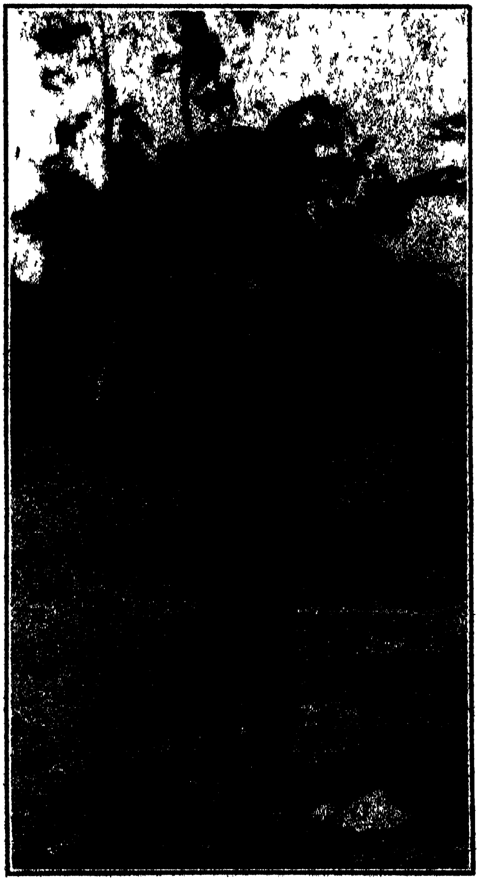
Then there was Damien Belibi, a young nuisance of unbelievable persistence and aggressiveness. His narrow nose and small mouth suggested a rich endowment from Semitic and Hamitic conquerors. If we gave out bananas or oranges Damien always wanted all his own share and half of as many other shares as he could take away from the others; they, strange to say, seemed to submit to his aggressiveness as if he were already a chief, instead of being only a relative of the chief. Good little Sylvanus Atangana would hold his baby brother by the hour and sit there on the piazza arrayed in a great green Caladium or perhaps Papaya leaf. He was quiet, obedient and smiling, but very inattentive; I gathered that he did not have nearly as much brain as the aggressive Damien. Utterly different from all the others was Aloid Amanana, whom I called the "young ascetic" for obvious reasons. One might attribute the prominence of his bones to disease, but what gave him the narrow nose and delicate mouth except perhaps inheritance from proud Hamites?

Minye Ngama, although the son of the old "king," was a dull, heavy-faced child, who inherited his father's powerful clutch on a metal franc. Nevertheless, he was one of my best sitters, as he was too stolid to flash about like some of the other children.

Some of my friends at home, who never saw the originals, were good enough to be highly entertained by my "portraits"; and such is the magic of self-deception that I long felt that I had captured the most essential features of these elfin faces. Unfortunately, or fortunately, I recently saw an actual photograph of these same boys and the effect was devastating to my pride; for by missing certain fundamental proportions of the parts, the details which I had so carefully noted were out of scale. However, I still think that my portrait of Petulis conveys a fair idea of his general make-up, and luckily Professor McGregor has no photograph of him to destroy the illusion.

After portraying the "king's son" my fame, or the fame of my francs, seemed to spread rapidly and I was besieged with prospective adult clients. I finally selected two of the most persistent candidates, Petulis, nicknamed the "Bonehead," and Eluna Lumbele, nicknamed the "Jolly Executioner," because he seemed to have been born for such a part. Petulis had very kindly tried to assist me in posing the models; and the fact that he invariably misunderstood what I wanted and was far more of a nuisance than a help is not set down in malice. He made an excellent model himself, however, first, because the occupation of earning a franc by merely sitting still appealed to his whole nature; secondly, because he was vain enough to admire the portrait; and thirdly, because his grand mouth and nose, sleepy, half-shut eyes and thick-topped skull were all salient features that could be recorded even by a novice.

And what a thrill I experienced when Eluna Lumbele presented himself for a portrait. He lived a little way up the road, and once when I walked by he hastened out to invite me to notice the fine new house he was building. On that occasion he wore only a loin cloth and I was impressed by his huge athletic frame, his small head and super-comic face. But to-day he was arrayed in all his dear-bought toggery, of which he evidently wanted nothing omitted. By gestures, copious language and broad smiles he intimated that I should dismiss my small boy model and begin with him. Such an opportunity was not to be lightly missed, so I quickly paid the boy his franc and sat Eluna down on the box on the back piazza. But what if the portrait should offend his dignity and he should start to mop up the would-be artist? It was getting late and I worked as I never worked before. Never had I seen such a wide nose, nor such an ample median bump on the forehead, nor more slit-like eyes, nor more decorative tattoo marks, nor a more self-satisfied ensemble. I did not dare to slight any of the tattoo marks on his face, as they were his heraldic devices, telling the world that he was every inch a Yaoundé man. At last it was too dark to go on, so I got my shaving mirror, gave him a good look at himself and then held up the nearly finished sketch. The bystanders roared approval, smiles stretched further his broad mouth and his eyes became slits. The fee of one franc made him more



—*Photograph by J. H. McGregor*

A YOUNG PRINCESS

—*Photograph by J H McGregor*

THE CHURCH AT OZOUM

happy and vain than ever. On the next sitting a few days later I corrected and finished the sketch (as far as I could). Then I suggested that he bring along his wife to view the portrait. Serious looks and dejected mien. "No got wife. Wife cost plenty, plenty francs. No got francs."

After that he was very assiduous in his attentions to me, frequently intimating that I should give him another franc and apparently hoping that I might even give him enough to purchase a wife for his new house. But I always laughed at him and made gestures signifying that he should give me francs for making his portrait.

One of my best sitters was Nga Mpuoko, a little girl of perhaps eight or nine years, who spent much time about our door. She was a remarkable little actress and could make the most comical faces with her almost ape-like lips. Also she gave an impressive imitation of the mourners at a funeral. She used to address us respectively as MACGRIGWARR and GRIGWARRÉE.

At night when all was still in the village, the sheep sometimes crowded up on our porch and wagged their tails so vigorously that our walls would shake. Large hairy spiders dwelt above the door and with a flashlight one could see the green gleam in their eyes. But we were secure under our tightly tucked-in mosquito netting and as long as the spiders seemed to be minding their own business we chose not to bother them. As to driver ants, the broad village plaza, picked clean of every blade, discouraged their invasions, although we once saw them streaming through a hut along the path.

While Raven and Chief Martin and several of his men were hunting gorillas I made several excursions in the forest near by, ostensibly in search of monkeys but really just to see the forest itself and whatever it might reveal to me. I took one of the chief's relatives, Andreas

Ysombe, as a guide. He was a tall, powerfully built man with regular features and a black beard. We wandered for several hours in the forest, which was very similar to that at Banalia, north of Stanleyville. The underbrush, thorns and vines offered only a moderate amount of opposition whenever we left the path and we seldom needed a machete. The forest was very still, except for the hubbub made by hornbills; monkeys were either very scarce or remarkably secretive. At one place Andreas warned me away from a pit which had been dug for wild pigs and antelope. Here he stopped a while and gave out a series of remarkably loud sounds, purporting to be antelope calls, but no antelope appeared. Then we went down the valley to the bed of a stream and Andreas motioned to me to climb up on his back. After I had done so he walked up the stream some distance until he found a suitable place to get through the bush on the other side. I then got down from my human steed and we came home.

On another occasion I took another man, named Benedict Nkudu, to a different part of the forest. He went through a similar performance of calling antelopes, but his rendition of the call was widely different from the other man's. Both these men could call antelope successfully, for the first one showed me many skulls and horns of large antelopes which he had called in this way, and the second afterward called two small ones successfully when he was out with Raven. On this day, however, his calls produced only an echo and we went on after monkeys. For a long time we did not see any, but after a while one or two began to leap from tree to tree. They retreated into the lowest and thickest part of the valley far more quickly than I could follow them. So I stood still and let the man go ahead. He was out of sight in a moment and I heard nothing of him for a long time, so I cleared away a few stems and sat down on them to study the forest. Pretty soon I saw a little movement in the tree and in a moment a beautiful spot-nosed monkey was creeping forward on a branch immediately above and in front of me. I kept very quiet and it was a minute or two before he discovered me and leaped away. After another short while a stick fell down out of the tree in front of me;—and there stood my guide, smiling, a little way up the hill behind me. He had used up the several bullets I had given him, but had shot no monkey. His foot was bleeding on the thick sole, where a stick or stone had penetrated it. He then cut a small switch and whipped the sole of his foot rapidly at the spot where it had been punctured until the blood flowed freely. Apparently this was a native method of preventing blood-poisoning. In a minute or two he was ready to proceed. By this time it was about ten o'clock in the morning and there was slight chance of our seeing any more monkeys until late afternoon, so we went back to camp.

The religious services of the church at Ozoum were one of the most remarkable features of the village. At matins, high mass and vespers the church was filled with men, women and children eager to take an enthusiastic part in the service. The French priest, Father Antoine, was very friendly and courteous to us and extended to Dr. McGregor and myself a cordial invitation to attend the early morning mass. Accordingly we went in to the church and took places near the door; but Father Antoine sent one of his black catechists after us and we were conducted to the front seat immediately in front of the chancel rail. As if this were not embarrassing enough, just before the time came for the people to kneel at the chancel rail, the black catechist again came to us and conducted us to two chairs which had been placed within the chancel, between the altar and the communicants. For nearly an hour the congregation took a lively part in the service, the frequent and sometimes long responses being given with vigor, precision and in perfect unison, all in the native language. This technical perfection was the result of daily practise conducted by the several catechists even while the priest was away visiting the many other villages under his care.

The children in the school were taught to read and write in their own language, chiefly for the purpose of being able to read the words of the prayerbooks and other religious books, which were their sole and sufficient literature. To teach them this and to enforce the discipline of the church naturally taxed all the strength and time of the priest and his catechists. There was thus no time or energy left to fight the fearful diseases that afflict the people or to teach them hygienic living, this apparently being regarded as the duty of the state.

When we came out of the church I saw an enormous millipede crawling slowly along on the open plaza. I admit that it was too "crawly" for my nerves, but I called McGregor and he grabbed it instantly and thrust it into his pocket. When the folks coming out of church saw this they screamed and scattered in all directions. Doubtless our prestige, in being able to handle such "deadly" critters with impunity, must have been greatly enhanced.

One bright day in Ozoum we heard a woman begin to cry out and moan. Immediately every one stopped what he was doing and began to drift across the street to a certain house where a younger brother of Chief Martin had just died. In a short time the news had traveled and people streamed in from every direction, mourning loudly. Soon the roar of the mourners was like the hum of an immense hive. The dead man's widow, reasoning in the native way, asserted that he had been poisoned. Chief Martin requested us to go to look at the body, which we did. McGregor assured him in German that we saw no evidence of poisoning, but that the man had more probably died from pneumonia. The chief told us that many people were killed by a "worm" that gnawed its way into the lungs, and that he himself had once been ill from this cause. That evening a fire was lighted in front of the house and the mourning chorus was renewed. Late in the night the body was carried to a near-by village. The next night the drums in that village were most insistent, and as I lay in bed listening to their magical rhythms it seemed to me that they must be describing the long journey that the dead man was making in the world of shades.

A few days later the widow returned to Ozoum, making loud and dismal lamentations as she entered the village road, which she continued for some little time after entering her house. But somehow I received the impression that a good deal of the public and private mourning was more or less overstimulated and that after the dead had been decently mourned the grief of all was assuaged and life went on much as before.

During these three weeks of persistent hunting Raven was assured many times and in many villages that there were "plenty, plenty ingagi" (gorillas) near by. But although he and his black assistants followed gorilla tracks for long distances and on two or three occasions came near to one or more gorillas, he was never near enough to shoot one through the head and he stuck to his policy of not taking random shots at the body. For on all his field work in many parts of the world he has been scrupulously careful never to kill a single individual more than he has a permit for, and it would annoy him extremely to wound an animal and let it get away. Although Chief Martin and his men were enjoying the opportunity to hunt gorillas with him and pressed him to stay on with them until he got one, Raven decided that he would try his luck in another district; so he came back to the village of Ozoum and we prepared to leave.

But before leaving we gave a little party for the children of the village, who had all been our friends for the past three weeks. McGregor and I walked down to Yaoundé, taking one of our personal boys, to purchase the material for the party. On the day before we left the native school-teacher marshalled his pupils and led them forth, chanting the school hymn. They drew up in front of our house in the presence of the chief and head men and were arranged in files of three each. McGregor and I then passed down the lines, distributing to each boy a handful of candies, a pencil, two heavy rubber bands for his bean-shooter and one franc. For the few little girls present we had candy and oranges. The whole affair was carried out in solemn silence, and we felt rather depressed at having unintentionally thrown such a wet-blanket over our usually light-hearted young friends. We returned to our porch and told the catechist that that was all. But he kept the children standing there and we retired into the house. In a few moments there was a mighty chorus: just "GOOD BYE!" but delivered with all the decision and unison of their religious services. It was not until late that afternoon that they plucked up courage enough to crowd around our piazza and beg for bananas and francs with their usual informality and persuasiveness.

Early next morning, when we and all our camp equipment passed down the mountain path, Nga and Détus and several others made the trip with us to the auto road. There we took leave of all our good friends, from Chief Martin down to Détus Ogmba, who said he was willing to go with us into the great world. And seldom have I been sorrier to part with friends anywhere in the world than with these engaging ex-cannibals of the Congo forest.

THE THUMB OF MAN

By Dr. EDWARD L. TROXELL

PROFESSOR OF GEOLOGY, TRINITY COLLEGE

We must acknowledge that with all his noble qualities, with his god-like intellect—with all these exalted powers—Man still bears in his bodily frame the indelible stamp of his lowly origin.—*Charles Darwin.*

MANY people are inclined to reject any theory of man's origin from a lower form of life because it seems to them ignoble. In their minds the evidences of such a beginning for the human race do not suggest mere humility, but rather constitute a stigma, a blot that causes a sense of shame; it is a thing to be concealed.

It is our purpose in the following pages neither to apologize for the course of events in our prehuman existence nor even to enumerate the many evidences, those stigmata, that show the trend of our ancestral development. Rather it is our plan to follow through a consecutive series of events that have, during some fifty million years, brought our race up from the earliest primates; we shall endeavor to trace the line of cause and effect that culminated in the achievement of man's highest mental and physical qualities.

In our treatment of the subject we shall put especial emphasis on certain new features, such as the development of the opposable thumb, the bending forward of the cranium, the reduction of the "animal" features of the face and the assumption of the upright carriage; but one should not lose sight of those old-fashioned characters, the scores of vestiges of once existing parts that constitute "the indelible stamp" of our humble origin.

It was at a time before the so-called age of mammals and well over a hundred million years ago, in the Mesozoic era, that certain animals began climbing trees for safety and for food; a new type of food, consisting largely of the fruits and nuts, was coming into existence at that time. At first these humble creatures climbed for their sustenance and security by using their claws just as many carnivores and rodents do to-day. Some of them ran on top of the branches, making use of their padded feet; but others learned to climb and cling by employing the first digit, the thumb, set off at an angle from the rest of the hand. This not only gave the hand a broader base, but with the thumb extended from the other fingers and opposing them the hand came to have a wrench-like grip that prevented twisting and slipping on the limb of a tree.

Out of the employment of the thumb, at first in climbing and gripping the branches of a tree, there arose other and higher uses for it, and eventually the thumb had the greatest significance in the progress of the human race. Let us follow the development and employment of the thumb, that member of the hand sometimes unwittingly held in contempt.

One should go back and trace, however briefly, the history of the animals that constitute the links in the chain of our ancestry and see what influence the structure of the hands and limbs may have had on the habits of life, the better to understand how it was possible for man, the upright one, to have been evolved. We begin with the earliest primates known in recounting this history and our minds go at once to the little *Pelycodus* of the early Eocene epoch. It has been our good fortune to find many specimens, consisting mostly of jaws and teeth, of this lemuroid once inhabiting the region of Wyoming. While we do not know the complete form of *Pelycodus,* yet its successor, the *Notharctus* of middle Eocene, is well represented by skeletons and separate bones in the American Museum, and it has been carefully studied and described by Granger, Gregory and others of that institution. *Notharctus* is thought, by those who are competent to judge, to have had at that early time just those qualities that one would expect to find in the ancestor of man and of the higher apes.

There is good reason to believe that *Pelycodus* and *Notharctus* (Gregory, 1928) had achieved already the prehensile hand and foot, the opposable thumb and great toe, and in them the foundation was laid for that structure without which our present civilization could never have been attained.

It is difficult to say just what progress was made in the use of the thumb by the succeeding primates, *Parapithecus* and *Propliopithecus* of the Oligocene period, but it seems highly probable that the well-known genus, *Dryopithecus,* had come to use the hands in many more ways than merely for hanging to the branch of a tree for support. Here in *Dryopithecus*—tree ape—we expect an ancestor that surely had learned to use the hands in gathering food, in arranging sticks for a comfortable nest and, above all, for holding objects before the eyes for closer scrutiny. Inquisitiveness was born. Curiosity had come to be a racial trait. What an impetus this would give to the development of a higher intelligence!

While it can not be said strictly that the presence of the hand itself was a cause, yet given a brain—from whatever cause—the hand stimulated and enhanced its better use. As the hand played to the mind so the mind to the hand and they mutually stimulated fresh and higher consequence. The hand furnished an instrument for the fuller development of the mentality and those creatures that chanced to have a higher brain capacity were able to use the hand to their greater advantage. A high reward awaited the possession and further employment of both. And so it came about that for millions of years there continued a selection in nature of that species of primate in which the mental capacity gradually improved.

This happy agreement between hand and mind brought about another signal step in the upward trend of this fortunate race. For some time the superior mental equipment and the useful hand had made these primates less dependent upon the great size and strength of the jaws, upon the number, form and arrangement of the teeth, upon the sense of smell and so on; the result was that the facial portion of the skull decreased in its proportions while the cranial dome used more and more material in its construction. Less and less of jaw, except that the chin lagged behind in its reduction, restricted were the teeth in size and number, fewer and fewer were the bestial propensities; instead there came more and more of that which stood for higher and nobler thoughts and actions. Always this was accompanied by the further training of hand and thumb and the course was laid that made it possible for these primates to achieve the highest place in the scale of life.

Observe a further progressive change. The brain, because of its tremendous development in this rapidly evolving race, began to occupy not only the back of the head, as in the earlier progenitors, but the top as well and it even crowded forward upon the region of the eyes and nose as the forehead encroached on the face. The results, pointed out especially by Tilney, were of the utmost importance: the nasal region became so compressed and restricted that the sense of smell was largely lost; the eyes were pushed forward and closer together resulting in binocular, stereoscopic vision. The skull was bent, even in prehistoric man, so far forward that no more could he see above his head or behind his back as did the earlier lemurs. It became virtually impossible for these creatures, standing on all fours, to see other than the ground beneath

Now note the significance of all this. There came a time when it was necessary for our ancient forebear to stand up or sit up in order to see what was before him. In moving about he was compelled to rise upon his two feet, to assume an upright posture, and he became man. Out of a series of events that seemed destined to turn his face inexorably toward the soil, there resulted an exaltation to a higher, more noble position. In many ways, indeed, it has proved a serious business, and often certain of our primitive organs find it more than they can endure. Many human ills arise from this new estate.

So long as our ancestors remained in the trees, perhaps throughout the time of *Dryopithecus* in the Miocene-Pliocene epochs, the bending of the skull forward made no great difference. As a matter of fact it may have been, as some strongly contend, that the first trend toward the upright posture had its inception in the trees. But certain it is that just at this time the environment offered a new and impelling influence; a change in climatic conditions, well recognized in the geological record, caused a wasting away of the forests that made it increasingly necessary for those ape-like beings to drop down upon the ground, to cover the distance from tree to tree, from grove to grove, on their feet.

It was then and thus that the quadrupedal gait was discovered to be entirely out of harmony not only with the hand but with the form and structure of the skull, and *Dryopithecus*—his name notwithstanding—was forced to make his way on foot upon the ground. He found that the bipedal gait was as convenient and essential as the quadrupedal method was awkward and unnecessary. As early man found it an advantage to stand upon his hind legs to see what was transpiring about him so every newborn babe to-day must discover for itself anew this interesting and important principle and each in turn must learn to rise from its hands and feet, a quadruped, and solve again the difficult problem of seeing and understanding the world about it.

And it was a fortunate thing that our ancestors were finally forced out of the trees in the Pliocene time, if we may judge by what happened to certain of the other primates. Take, for instance, the spider monkey (*Ateles*) that has lost its thumbs entirely, or the gorilla, chimpanzee, etc., whose thumbs are greatly reduced, and it becomes evident from these examples that we too might have been deprived of the use of this most important member, had our race remained in the comfortable trees. Without the thumb the life of modern civilized man could never have been a possibility.

We review the sequence of events:

The thumb separates to give broader "footing."

The hand learns to grasp the branch of the tree.

Useful as a tool, the hand stimulates the mentality.

Result, increased capacity and power of the brain.

Bone from the face goes to enlarge the cranial roof.

Nose, jaws and teeth decrease in size and function.

Forehead crowds the eyes to a place of greater vantage.

The eye and hand still more faithfully serve the brain.

The face bent forward forces man to an upright posture.

Bipedal gait frees the hands to further assist the brain.

Upright man reveals the remarkable evidence of his progress.

But still shows the "indelible stamp" of his humble origin.

THE CREATIVE YEARS IN SCIENCE AND LITERATURE

By DR. HARVEY C. LEHMAN

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WHAT are man's most creative years? At what ages are men likely to do their most outstanding work? In 1921 Professor Robert S. Woodworth,[1] of Columbia University, published this statement in his book, "Psychology: A Study of Mental Life":

> **Seldom does a very old person get outside the limits of his previous habits. Few great inventions, artistic or practical, have emanated from really old persons, and comparatively few even from the middle-aged . . . The period from twenty years up to forty seems to be the most favorable for inventiveness.**

Writing under the fictitious name, Helen Nelson,[2] an author whose article appears in the *American Journal of Psychology* takes vigorous exception to Woodworth's foregoing assertion After arguing at length against Woodworth's statement, Miss Nelson lists a number of individuals who did notable work after they had reached the age of forty. Presumably upon the basis of her citations, Miss Nelson arrives at the following conclusion:

> **. . . in the case of these names at least, invention of the highest order, far from being in decay at forty, seems to be at the very prime or just ready to begin.**

The *method* by which one arrives at a conclusion is no less important than is the conclusion itself. For example, if a writer or a speaker should attempt to describe seriously incidents that were alleged to have occurred on the opposite side of the moon, the critical listener would (or should) immediately ask *how* the speaker had obtained his alleged information. And, if queries regarding the problem of technique could not be answered definitely and to the entire satisfaction of the interrogator, intelligent auditors would probably see no reason for taking the speaker's remarks very seriously.

The same principle should hold for reports which deal with human behavior. If credence is to be given to research findings it is always important to know *how the alleged findings have been obtained.* Certainly, the serious student is entitled to know whether the research worker was prejudiced or whether, like the expert athletic official, he was able to view with an attitude of calm detachment the phenomena which he claims to have observed.

It is one thing to set out with a ready-made conclusion and to search for illustrations that may be employed for the purpose of proving its validity. It is quite another thing to assemble factual data and, while doing so, to maintain an impartial attitude. In the article previously referred to, Miss Nelson seems rather obviously to have employed the first of the above-mentioned techniques and, writing in an inimitable literary style, she proceeds (by the selection of some exceptional cases and the omission of others) to defend her belief that old age is the most favorable time for inventiveness.

Literary skill and the ability to persuade are not valid substitutes for sound research technique. With this elementary principle in mind let us see what is to be found when the inductive method is employed as the means for studying "the creative years." We, of course, shall not attempt to canvass all kinds of endeavor. Such a large undertaking would be impossible of accomplishment. Let us therefore limit our inquiry. Let us first examine the field of creative chemistry and attempt to answer the following question. Do chemists display more creative thinking at some chronological age levels than at others?

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[1] R. S. Woodworth, "Psychology: A Study of Mental Life," p. 519. Henry Holt and Company, 1921.

[2] Helen Nelson, *The American Journal of Psychology,* 40: p. 304, 1928.

In his book, "A Concise History of Chemistry,"[3] Professor T. P. Hilditch, of the University of Liverpool, presents the names of several hundred noted chemists and the dates on which these chemists made their outstanding contributions to the science of chemistry.[4] Professor Hilditch's book was chosen for study for several reasons. In the first place, Hilditch is an able worker in the field of chemistry and his institutional connection is above suspicion. It obviously would have been an absurd and a wholly indefensible procedure for the present writer to have attempted to evaluate the work of noted chemists

It was stated previously that Hilditch is an able chemist. But even this fact did not satisfy the present writer Hilditch's judgment might be after all "only one man's opinion." Professor Hilditch's book was submitted therefore to four different university teachers of chemistry. These four chemistry teachers were unanimous in their judgment that the contributions listed by Hilditch form an essential part of the chemistry panorama. On the basis of the collective judgments of these advisers, the writer concluded that Hilditch's list is probably a fair and adequate sampling of outstanding achievement in the field of creative chemistry.

There is a second reason for utilizing the list of achievements that was set forth by Hilditch. When he was selecting important contributions in the field of chemistry, Professor Hilditch was *not* studying age differences in creativity. He was probably therefore not even aware of age differences. This fact is of considerable importance in so far as the present study is concerned. Certainly, when studying the creativity of persons of different chronological ages, an investigator should divest himself of all bias for or against any particular age levels. And this impartial attitude is most likely to be attained when the compiler of a list of outstanding achievements is thinking *not* of age differences but solely of outstanding achievement.

If each age group is to be judged fairly it is necessary to take account of a number of other things. For example, one must consider the number of individuals that are alive at each successive age level. Certainly, if more men are alive at the younger age levels than at the older age levels, the younger age groups might achieve more merely because of their greater numerical strength. Adequate allowance for the unequal numbers of individuals alive at the various age levels was therefore made in a manner that will be hereinafter described.

One final word with reference to the problem of technique. It obviously is not possible to study the entire life work of individuals who are still living and achieving. In the first place, it is almost impossible to judge the real significance of quite recent work. Moreover, we have no way of knowing what the living chemist will accomplish during his later years. The present study includes therefore data for deceased chemists only.

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[3] T. P. Hilditch, "A Concise History of Chemistry." D. Van Nostrand Company, 1911.

[4] Subsequent personal correspondence with Professor Hilditch elicited the following statement regarding the dates of achievement: ". . . the dates given in my history as those in which contributions were made are simply the dates of first publication of the results in a scientific journal or similar medium. In general I would say that these dates would be within a year of the time when the discovery, etc., was actually made. The interval might be less than this, but would rarely be more."

For the deceased chemist the record is reasonably complete and future events will probably change the record only slightly.

In so far as data were available, the birth and the death dates of the chemists listed by Hilditch were secured from histories of chemistry and from various other sources. With the foregoing information it was possible to determine the chronological ages at which the world's most renowned chemists made their most significant contributions, both theoretical and experimental, to the science of chemistry. The findings are set forth in graphic form in Fig. 1.

Fig. 1 presents the chronological age levels at which 244 chemists (now deceased) made 993 significant contributions to the science of chemistry. In Fig. 1 the histogram (the line containing many right angles) presents the data by yearly intervals; the polygon (the curved line) presents the same data grouped by five-year intervals. In studying Fig. 1 it should be borne in mind that this figure presents the *average* number of chemical contributions per chronological age level. Full and adequate allowance is thus made for the larger number of youthful research workers.

For example, it was found that at age twenty-nine, 244 chemists made 49 contributions. This was slightly more than an average of .2 of a contribution per individual. Of the 244 chemists that were alive at age twenty-nine, 220 were living at age 50. The 220 workers that remained alive at age 50 made only 23 contributions, which was slightly more than .1 of a contribution per living chemist. In Fig. 1 the histogram is so drawn as to be only about half as high at age 50 as at age 29. The histogram is drawn in this manner in order to show graphically that the *average* number of chemical contributions per living individual was only about half as large at age 50 as it was at age 29.

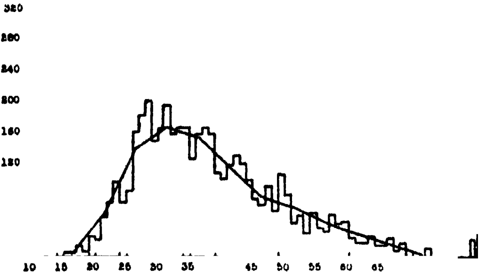

Fig. 1. Average number of contributions by chemists in each year of their lives. This graph is based on 993 significant contributions that were made by 244 noted chemists.

If, regardless of the number of workers that remained alive, the fifty-year-old chemists had contributed *at the same average rate* as did the twenty-nine-year-old chemists, the curve in Fig. 1 would have remained as high at the fifty-year-old age level as it is at the twenty-nine-year-old age level. Actually, the curve in Fig. 1 exhibits a very noticeable descent at the older age levels. Why does this marked descent occur?

A copy of Fig. 1 was mailed to Professor Hilditch. In commenting upon it, Professor Hilditch wrote as follows:

> Frankly, I am surprised that your analysis of the data leads so clearly to the age range of about 30 to 35 being the most productive for chemists. One cannot, of course, dispute the accuracy of a mathematical analysis of this kind, and yet the results are contrary to what one would have anticipated.
>
> I am not surprised that the maximum productivity should appear by about the age of 30, but I would have expected this maximum to be more or less sustained over the succeeding 20 or 25 years. I think it would be generally agreed amongst chemists that the productive type as a rule continues to develop and *mature* until well on into what is generally called the prime of life.

The present writer requested several friends to explain why the curve in Fig. 1 rises so much more rapidly than it descends, and why it descends so quickly after reaching its maximum. One individual suggested that the older chemists may have become more discriminating during their later years and that the

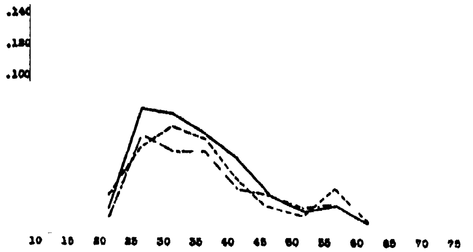

FIG. 2. CHRONOLOGICAL AGES AT WHICH THE MOST IMPORTANT CHEMICAL CONTRIBUTIONS WERE MADE, BASED UPON THE ESTIMATES OF THREE JUDGES. AVERAGE NUMBER OF CONTRIBUTIONS PER FIVE-YEAR INTERVAL

older men may therefore have disdained to publish findings which they regarded as of minor importance. If this explanation were a valid one the contributions of the older men should be superior in quality to the contributions of the young chemists. As a means of ascertaining the facts with reference to this matter, three of the writer's colleagues[5] from the chemistry department of Ohio University were asked to select the 100 *most important* or *most significant* chemistry contributions that were listed in Hilditch's book. The three collaborators were asked to make their selections without consulting one another and to make them from the point of view of the chemist rather than that of the layman. The peaks of the resultant curves appeared *at slightly younger ages* than the peak of Fig. 1 (see Fig. 2). Clearly, the alleged superior discriminative ability of the older men does not explain why maximum productivity occurs at such a relatively early age. Apparently, the most significant contributions to the science of chemistry have been made most frequently by individuals who were approximately thirty years of age at the time of making their invaluable contributions.

A chemist of more than national reputation was asked to explain why maximum productivity, as revealed by Fig. 1, is not sustained for a longer period of time. This chemist expressed the opinion that the early descent of the curve in Fig. 1 is due to the fact that the young chemist who displays marked ability by the early publication of important research findings is likely, sooner or later, to be advanced to an administrative position. That is to say, the more gifted young chemist is often made head of his department or placed in some other administrative post which absorbs his time and energy and precludes further research. The speaker added that it was his belief that the total amount of chemistry research might be greatly increased if the foregoing practice were to be abandoned.

If the present study had been limited solely to the creative work of chemists, one might accept the above hypothesis. However, age-curves similar to Fig. 1 were constructed for inventors, physicists, mathematicians, astronomers, poets, short-story writers and several other kinds of workers (see Figs. 3 to 9).[6] It is true that the precise age

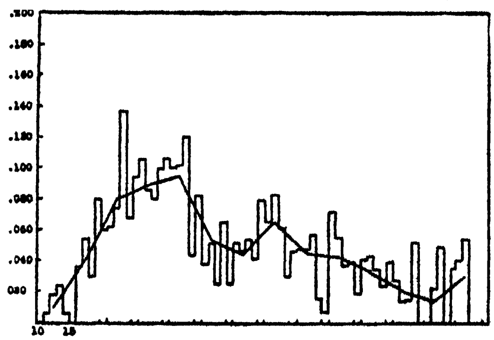

FIG. 3. AVERAGE NUMBER OF CONTRIBUTIONS BY MATHEMATICIANS DURING EACH YEAR OF THEIR LIVES. THIS GRAPH IS BASED ON 453 CONTRIBUTIONS THAT WERE MADE BY 163 MATHEMATICIANS.

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[5] Professors Donald R. Clippinger, Frank B. Gullum and J. R. Morton gave cheerful and whole-hearted cooperation to this phase of the study.

[6] The data that were employed for the construction of figures 3 to 9 inclusive were obtained in a manner similar to that which was utilized for obtaining the data that were used for the construction of Figure 1. It is assumed that the reader will be more interested in the findings that were obtained than in a detailed description of the technique that was employed. Therefore most of the remainder of this manuscript will be devoted to a presentation of the findings.

level at which the several curves reached their peaks varied somewhat. The shapes of the curves also differed. Nevertheless, for most kinds of endeavor that the writer has thus far studied, the peak has been found to appear at a relatively youthful age. Therefore, the theory that the early and marked decrement in the productivity of the chemists was due solely or even largely to the pressure of administrative and classroom duties is of very doubtful validity.

The data that are presented graphically in Fig. 3 were obtained from Cajori's "A History of Mathematics"[7] in the following manner. The author of this article first checked through Cajori's history and noted each mathematical contribution that was dated. By this means a total of 1,092 specific dates was obtained. A colleague[8] from the mathematics department was then requested to check from the writer's list those contributions which might be regarded as the most significant. After this had been done the list included 718 dates. Some of these were later discarded because they were duplicates; others were discarded because the birth or the death date of the contributor could not be found.

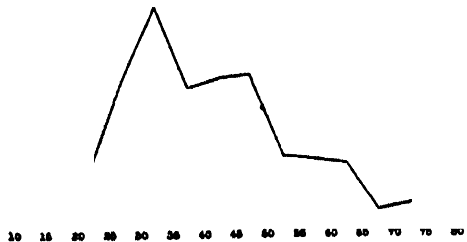

FIG. 4. AVERAGE NUMBER OF CONTRIBUTIONS BY PHYSICISTS DURING EACH YEAR OF THEIR LIVES. THIS GRAPH IS BASED ON 141 CONTRIBUTIONS THAT WERE MADE BY 90 PHYSICISTS.

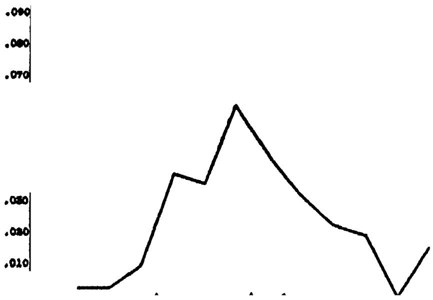

FIG. 5. AVERAGE NUMBER OF CONTRIBUTIONS BY ASTRONOMERS DURING EACH YEAR OF THEIR LIVES. THIS GRAPH IS BASED ON 83 ASTRONOMICAL CONTRIBUTIONS THAT WERE MADE BY 63 ASTRONOMERS.

The data that were employed for the construction of Fig. 4 were obtained from William Francis Magie's "A Source Book in Physics."[9] This source book, which was first published in 1935, contains extracts from what Magie regards as the most important contributions that have been made to the science of physics during the past three centuries. It will be seen at a glance that Fig. 4 bears much similarity to the figures that have preceded it. Like the other curves this one rises much more rapidly than it descends and the period of maximum productivity is not later than from ages 30 to 34, inclusive.

The data that were employed for constructing Fig. 5 were obtained from "A Source Book in Astronomy"[10] by Shapley and Howarth. It differs from the preceding curves in that the peak of productivity occurs somewhat later, namely, between ages 40 to 44, inclusive. A part (possibly all) of this difference may be due to a difference in the amount of time lag that occurred between date of accomplishing and date of first publication. For 75 of the 83 astronomical contributions (90 per cent.) only the dates of first publication were available. Obviously these dates of first publication do not tell the chronological ages at which the contributions were actually made. We know only that for the 83 astronomical contributions the peak of productivity occurred *not later than* ages 40 to 44, inclusive.

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[7] F. Cajori, "A History of Mathematics," Second Edition. New York: The Macmillan Company, 1922.

[8] Thanks are expressed herewith to Professor Robert H. Marquis.

[9] W. F. Magie, "A Source Book in Physics." McGraw-Hill Company, Inc., 1935.

[10] H. Shapley and H. E. Howarth, "A Source Book in Astronomy." New York: McGraw-Hill Book Company, Inc., 1929.

If the present study had been limited to the creativity of scientists only, one might have been led to the spurious belief that classroom and administrative duties are the sole reasons why the foregoing curves start descending at such relatively early ages. A glance at the curve for great inventions should suffice to dispel such a belief. Fig. 6 presents the chronological ages at which 554 notable inventions were made by 402 well-known inventors. Since it sets forth *the average number of inventions per chronological age level,* this figure is comparable with the figures which precede it. The names of the inventors and their inventions were procured from sources some of which are listed in the footnote [11]

When Fig. 6 was displayed to interested colleagues several commented, "What about Edison?" It is of course well known that Thomas A. Edison was very active as an inventor throughout his entire life. However, age 35 was Mr. Edison's most productive year. Moreover, during the four-year interval from ages 33 to 36 inclusive, Edison took out a total of 312 United States patents. This was more than a fourth (28 per cent) of all the United States patents that were taken out by Edison during an inventive career that lasted for more than 60 years. Most of the data that were employed for the construction of Fig. 7 were obtained from Edison's official biography.[12]

Fig. 8 presents the average number of short stories per chronological age level per short story writer. This figure is based upon 1,396 short stories that were written by 220 writers. Data were obtained from Jessup's "Representative Modern Short Stories."[13] The dash line near the center of the figure presents data regarding the production of the 66 "best" short stories, which were written by 37 different authors. The "best" short stories were identified by examining books and lists that contained what were alleged to be the "best" short stories. Those stories which appeared most often in such lists were accepted as "the best." For the "best" short stories the age interval of maximum productivity is not later than ages 30 to 34, inclusive.

Fig. 9 presents data regarding *dates of composition* for 797 great poems. The sources from which the data were obtained (English, American and German) are listed in the footnote.[14] Since it presents not dates of first publication but dates of composition, this figure is not directly comparable with the graphs that have preceded it. The period of maximum productivity for poetry seems to occur relatively early, namely, from ages 22 to 35, inclusive. Beyond age 35 the composition of poetry appears to decline rather markedly. The rise at the extreme right end of the curve is possibly significant, although it may also be accounted for in part by the fact that very few of the poets were alive at the age of 80. Average productivity at this advanced age may therefore not be trustworthy.

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[11] (a) "The Lincoln Library of Essential Information," The Frontier Press Company, 1934. (b) H. W. Ruoff, editor, "The Standard Dictionary of Facts." The Frontier Press Company, 1910. (c) E. W. Byrn, "The Progress of Invention in the Nineteenth Century." New York: Munn and Company, 1900. (d) "The Scientific American Reference Book." Compiled by A. A. Hopkins and A. R. Bond. Munn and Company, Publishers. Scientific American, 1905. (e) A. P. Usher, "A History of Mechanical Inventions," McGraw-Hill Book Company, Inc., 1929. (f) The *World* Almanac, 1935.

[12] F. L. Dyer, T. C. Martin and W. H. Meadowcroft, "Edison: His Life and Inventions." Harper and Brothers Publishers. In two volumes, vol. 2, pp. 975–1008, 1929. The writer is indebted to Mr. Henry Lanahan, general counsel of the Edison Company, for assembling and forwarding the necessary supplementary information.

[13] A. Jessup, "Representative Modern Short Stories." The Macmillan Company, 1929.

[14] (a) C. H. Page, "British Poets of the Nineteenth Century." New edition by Stith Thompson. Benj. H. Sanborn and Company, 1929. (b) C. H. Page, "The Chief American Poets." Houghton Mifflin Company, 1905. (c) B. J. Vos and P. A. Barba, "German Lyrics and Ballads: From Klopstock to Modern Times." Henry Holt and Company, 1923.

The reader will perhaps share the writer's skepticism that the early and marked decrement in the productivity of the chemists was due solely or even largely to the pressure of administrative and classroom duties when he learns that the age-curve (Fig. 6) for great inventions is very similar to the age curve for chemical contributions. Surely, it would be nonsensical to assert that the decrement in productivity among inventors was due also to the pressure of administrative and classroom duties To what, then, was the decrement due? Were the older scientists incapable of producing at the same rate during their more mature years as they had produced when younger? And, if they were fully as capable of producing when older, why did they fail to continue their creative work? Some might suppose that, when the older scientist has won fame and professional recognition, the prestige-motive that may have been eliciting strenuous and sustained effort might in some instances wane or even disappear. But would this be true also of the inventor and the short-story writer?

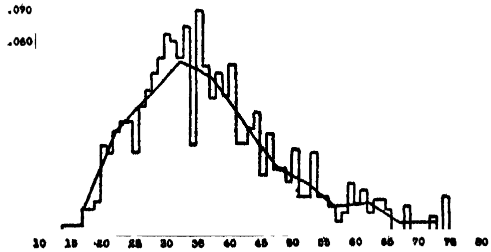

FIG. 6. AVERAGE NUMBER OF INVENTIONS BY INVENTORS DURING EACH YEAR OF THEIR LIVES. THIS GRAPH IS BASED ON 554 INVENTIONS THAT WERE MADE BY 402 INVENTORS.

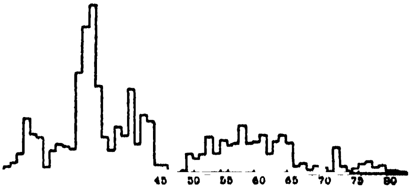

FIG. 7. NUMBER OF INVENTIONS THAT WERE MADE AT VARIOUS AGE LEVELS BY THOMAS A. EDISON. THIS GRAPH IS BASED ON A TOTAL OF 1,076 PATENTS.

School texts usually picture the renowned scientist as a man of rather advanced years. The present findings suggest that in a number of fields the typical outstanding scientist is an individual who is in his late twenties or in his thirties at the time he is doing his most important creative work.[15] This fact is not a very important one so far as the scientist (or the layman) is concerned. The finding is one that will be of interest chiefly to the serious student of human behavior. The discrepancy, between the scientist as he actually is when he is at work and the stereotyped concept of the scientist, is probably due in part to the fact that personal fame spreads rather slowly. By the time the scientist has become an old man his fame is likely to be at its height and his photograph often taken. Under such circumstances the photograph may give rise to an erroneous impression.

It should not be assumed that Fig. 1 sets forth, for every type of work, the relative creativity of men of different chronological ages. The writer does not mean to convey the impression that he has obtained typical creative-work curves. Indeed, he doubts very much that such a thing as a typical creative-work curve exists. This entire problem is of course one that is very complex. We need age-curves (or statistical distribution tables) for each kind of creative work. For, if one wishes to study the relative creativity of men of different chronological ages, the simple arithmetic average is insufficient. A simple hypothetical illustration will demonstrate the truth of this latter assertion.

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[15] Subsequent to the preparation of this manuscript the writer finds that in his "Dynamic Psychology," 1918, p. 130, Professor Robert S. Woodworth arrives at practically this same conclusion.

Let us suppose, for example, that nine chemists have each made one contribution to their science. Let us assume also that one of the nine made his single contribution at age 80, that two of the others each made their contributions at age 50, and that the remaining six chemists each made contributions at age 30. In the foregoing hypothetical situation, the sum of the contributors' ages at the time of contributing is 360, and the average age at the time of making the contributions is $\frac{360}{9}$ or 40. Now, in spite of the fact that the average age of the contributors is 40, six of the nine contributions (two thirds of them) were made prior to age 40, namely, at age 30.

The situation is similar for the 993 chemistry contributions that are pictured in Fig. 1. For the 244 chemists, the average age at the time of making a contribution is slightly more than 38. But the five-year interval of maximum productivity is from ages 28 to 32, inclusive! This latter fact is one that would not be known if only the arithmetic average were available. Nor would the arithmetic average have revealed the fact that the curve in Fig. 1 rises so much more rapidly than it descends.

Inspection of the curve in Fig. 1 will help the reader to understand why this is true. If, in Fig. 1, the two sides of the curve were wholly regular and symmetrical, the average would yield a fairly accurate impression. For, in that case, one half of the contributions would have been made at ages younger than the average, and one half would have been made at ages older than the average. But in Fig. 1 the curve is not symmetrical. Because of this the average fails to reveal an adequate picture of the facts.

When inferences are to be drawn one must always guard against going beyond the factual data. For example, some might infer that Fig. 1 reveals the rise and the fall (by chronological ages) of the chemist's social and scientific usefulness. Such an inference would be wholly indefensible. The writer would remind such readers that, during their more mature years, the chemists that are included in this study may have been doing highly useful work of a kind that does not leave tangible results that can be dated. Thus, some of the older chemists may have been engaged in administrative work. And, even though this may not have been the chief reason for the diminution of their creative research work, the administrative work was very probably socially useful. Others of the older chemists may have been directing laboratories and teaching younger men the technique of chemistry research. It would of course be absurd to assert that the athlete could achieve equally good results without the counsel and advice of experienced athletic coaches. The situation is probably analogous for young chemists.

Some of the older chemists may therefore have been making their later contributions *through their students.* To some extent this hypothesis is undoubtedly valid. There probably is such a thing as "creative teaching." And, although its results do not show up in Fig. 1, this creative teaching may be fully as important to society as is that which is customarily referred to as scientific productivity. However, data for inventors, poets and certain other groups of workers should suffice to convince the impartial reader that the foregoing hypothetical "reasons" do not explain why the curve in Fig. 1 wanes so noticeably beyond age 39.

One can hardly refrain from further philosophical speculation with reference to these findings. During the years that have passed, certain writers have assumed that the genius is one who is extremely capable, and some have assumed also that "genius will out." If this latter assertion be a valid one, why is it that the contributions of outstanding chemists (and certain other kinds of workers) decrease so rapidly during the workers' more mature years? Shall it be assumed that the world's most renowned chemists possessed *more genius* at ages 30 to 35 than was possessed by them at older chronological age levels? Certainly, such an assumption does not seem very plausible to the present writer.

Some have insisted that scientific discoveries are often very much like the finding of a five-dollar gold piece lying at the noon hour on the sidewalk at a busy street corner. Some one is bound to spy the coin. In other words, it is asserted that for years before it is seen, the discovery is "just waiting to be picked up." If this hypothesis be a valid one, why is it that the younger scientists find so many more of the "gold pieces" than do the older ones?

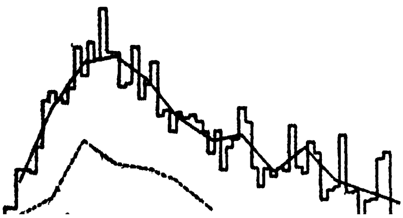

FIG. 8. AVERAGE NUMBER OF SHORT STORIES BY WRITERS DURING EACH YEAR OF THEIR LIVES. THIS GRAPH IS BASED ON 1,396 SHORT STORIES THAT WERE WRITTEN BY 220 INDIVIDUALS. THE DASH LINE PRESENTS INFORMATION REGARDING 66 "BEST" SHORT STORIES THAT WERE WRITTEN BY 87 DIFFERENT INDIVIDUALS.

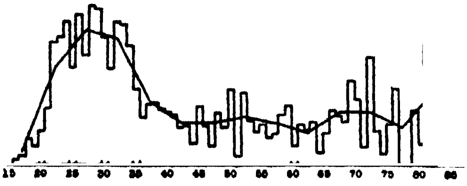

FIG. 9. AVERAGE NUMBER OF POEMS BY POETS DURING EACH YEAR OF THEIR LIVES. THIS GRAPH IS BASED ON A TOTAL OF 797 POEMS BY 82 POETS.

Assume for the moment that the alleged genius is merely the product of his environment, the instrument through which an idea or a creation receives expression. Why, then, are the thirty- and the thirty-five-year-old chemists, rather than the fifty- or the sixty-year-old chemists, so much more frequently the instruments through which the creation receives expression? Here certainly is a conundrum for the student of human behavior. The writer is not so rash as to pretend that he has entirely satisfactory answers to such queries as these.

In considering the results that have been set forth here, the reader should not overlook the fact that large individual differences exist.

It is certainly true that some individuals do their very best work when they are relatively old, and some do little that is really worth while until they *are* relatively aged. Therefore, if an individual has failed to make a chemistry contribution by the time he has reached the age of 35 or 40, it would be quite erroneous to assume that he will never make a contribution.

For the purpose of studying this the writer isolated data for 100 chemists, each of whom had made one contribution only that was dated by Hilditch. The data for these 100 chemists reveal

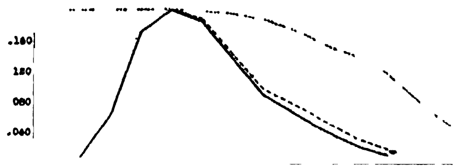

Fig 10 Total contributions (by five-year intervals) of 244 chemists. ——— Actual total; ---- Hypothetical total; .... Percentage of the original number of chemists that remained alive at successive age intervals. Figures at right represent percentages.

that 34 per cent of them made their first and only important contribution after they had passed age 40; 19 per cent. made their single contribution after they had passed age 50; and 5 per cent. did their first important research after they had passed age 55. One individual made his single noteworthy contribution at the age of 69! These individual differences suggest that it would be futile to attempt to ascertain the one chronological age level at which the chemist's social and scientific usefulness is at an end. Indeed, there probably is no such age level.

In Fig. 10 the solid line presents, by five-year intervals, the total number of contributions for the entire group of 244 chemists. This solid line in Fig. 10 made no allowance for the fact that more of the chemists were alive at some age levels than at others. In other words, Fig. 10 presents an undistorted picture of the actual number of contributions for each chronological age level. The dotted line in Fig. 10 presents the percentages of the original number of chemists that remained alive at successive age levels. This dotted line in Fig. 10 is so drawn as to be roughly comparable to the solid line in the following way. Had the living chemists contributed during their later years at the same rate as they were contributing from ages 30 to 34, inclusive, the solid line, which represents actual contributions, would have coincided with the dotted line which represents the percentages of the original number of chemists that remained alive at successive age levels.

The serious student of human behavior is, of course, not greatly interested in *what might have happened* under hypothetical conditions which did not actually exist. The psychologist is vastly more interested in *factual data*. Nevertheless, as a means of focusing attention upon the recorded facts, it may be worth while to speculate for a moment with reference to *what might have been*. Be it remembered, however, that this speculation is merely a device that is here employed for the purpose of presenting the true story of *what really happened*. With that fact firmly in mind let us proceed.

The dash-line in Fig. 10 is based upon the assumption that (had they lived) the deceased chemists of a given chronological age level would have contributed at about the same rate as did the group of living chemists of the same chronological age level. For example, at ages 65 to 69, inclusive, the deceased group was about 70 per cent. as large as the living group. It is here assumed that if this group of deceased chemists had remained alive they would have increased the contribution of the living group by about 70 per cent. Since, however, the contribution of the living group from ages 65 to 69, inclusive, was actually rather small, being only 10 contributions, a 70 per cent. increase would have raised the total by only 7 contributions—hardly as much as might have been anticipated.

If the foregoing assumption (that the deceased chemists of a given age level would have performed about like the living chemists of corresponding age level) is a valid one, the narrow band of space between the solid line and the dash-line in Fig. 10 represents that fractional decrement in scientific productivity which was due to the death of some of the chemists. Fig. 10 thus enables us to make a rough hypothetical estimate of two things, namely, (1) the decrement in productivity which was due to death, and (2) the decrement which was due to factors other than death.

It will be noted at once that that decrement in scientific productivity which was due to death is relatively slight as compared with that much larger decrement which was due to factors other than death. If all the 244 noted chemists had lived until they were 80 years of age they probably would have made 57 more contributions than actually were made by them. This hypothetical increase amounts to slightly less than 6 per cent of the actual total of 993 contributions. If those chemists who actually did live to a ripe old age had continued during their later years to contribute at the same rate as they were contributing from ages 30 to 34, inclusive, the total number of their contributions would have been 1,782 instead of 993. This would have amounted to an increase of 80 per cent. over and above the actual total of 993 contributions.

It was stated previously that the computation (80 per cent.) should not be taken too literally. We say this because society obviously can not lose that which it has never possessed. Moreover, the computation, 80 per cent., is based upon several unproven and unprovable assumptions. For example, this computation assumes that the number of possible chemistry contributions is practically unlimited; and that a given contribution does not depend upon antecedent contributions and cumulative social gains. Granted that the figure, 80 per cent., represents no actual social loss, the fact remains that our hypothetical computation demonstrates an actual and a very large decrement.

To those who regard scientific information as the most precious asset that the human race has accumulated, the above findings will perhaps bring a feeling of regret. Such persons may wonder if steps might not have been taken for increasing the scientific productivity of the older men. It is theoretically conceivable that an educational foundation, or some wealthy individual, might relieve the more capable research men of their routine and other time-consuming duties. If it be assumed that the older men have not lost their ability to do outstanding research work, the problem of actually motivating them (and certain other problems) would still remain unsolved It is not always an easy matter to motivate a child—or even a white rat. How, then, would we proceed if we wished to motivate a Steinmetz? Or the poet who composes beautiful and immortal lyrics? (See Fig. 9.)

When he was thirty-five years of age Thomas A. Edison took out a total of 104 patents during the course of a single year. If he had maintained that same pace during the remainder of his life Edison would have given to the world approximately five times as many inventions as he actually contributed. Who would

TABLE I

Average Number of Contributions Per Five-Year Interval*

Type of contribution	CA interval														
	10–14	15–19	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80–84	85–
Chemistry .		.005	052	.138	.165	154	.115	078	063	.044	.026	.014	.022	.000	.004	
Mathematics		.011	.041	.081	.090	096	.054	.045	.065	.045	.043	.034	030	.014	.031	
Physics		000	020	.017	.070	.043	.046	.047	.021	.020	.020	.005	.006			
Astronomy .		003	003	.010	.039	036	.061	.045	.033	.023	.020	000	.016	000	.000	048
Invention ..		006	.031	.043	054	.052	.036	.021	017	009	.010	.003	.003	.000	003	
Short-story writing		.001	.057	.175	.248	257	.218	.160	.122	.130	.070	.106	.059	.037	.021	
Great poetry	.002	.041	.310	.434	.404	.197	.136	.133	.153	.136	102	.168	.161	.117	.234	.058

* The peak of each statistical distribution is underlined.

TABLE II
SUMMARY OF FINDINGS WITH REFERENCE TO CREATIVITY

of [illegible]	No. of workers	No of works	Medial age		Standard deviation	Years of maximum productivity
Chemistry ..	244	993	35.95	38.08	10.45	28–32
Mathematics.	163	453	37.88	41.12	14.10	34–38
Physics	90	141	38.00	39.34	11.05	30–34
Astronomy .	63	83	44.20	45.09	12.00	43–47
Invention ..	402	554	35.27	36.71	11.10	31–35
Short-story writing ..	220	1,396	38 17	40 75	11.90	33–37
Great poetry	82	797	32.86	38.18	15.75	26–30

criticize Edison unfavorably because he failed to do this? And who would cast aspersions on the world's most gifted chemists because of the decline in their productivity? Certainly, the present writer does not mean to imply that the scientist exists solely for the purpose of making scientific contributions. Indeed, this study makes no assumption whatsoever as to what ought to be. Nor is this investigation concerned primarily with the problem of *ability* to do creative work. On the contrary, we are here dealing only with *performance* — the specific kinds of performance that have been set forth.

Upon the basis of the foregoing data, what is one to conclude? Do the decrements in creativity at the older age levels imply a corresponding decrement in ability to create? Certainly not! It seems probable that outstanding potential ability must be present in the individual who makes original and noteworthy contributions in any field. However, potential ability alone does not guarantee accomplishment. Indeed, it is doubtful that genius is solely the fruit of any single trait. It is the belief of the writer that the fruits of genius are, on the contrary, a function of numerous integers, including both the personal traits of the individual worker, environmental conditions that are not too hostile, and the fortunate combination of both personal traits and external conditions. If the foregoing hypotheses be valid ones, the following conclusion seems inescapable. At the older chronological age levels, some one or more of the numerous variables that are essential to the fruition of genius tend either to wane or to disappear. At the present time we are not able to identify all the factors that enable a particular individual to exhibit genius. Therefore, in instances where the fruits of genius are lacking we are not able to state precisely which of the needed ingredients are wanting. As regards the decrement that has been set forth herein, it can be said only that the decrement is probably due not to any single causal factor but rather to a complex group of undetermined causal factors. Any statement much more specific than the foregoing would obviously be highly speculative and of doubtful validity.

NOTE: Subsequent to the preparation of the above article the writer has constructed age curves for more than forty kinds of endeavor. These curves serve to confirm the writer's belief that generalizations regarding the creative years need to be made with extreme caution. For example, it has been found that literary masterpieces of the first rank have been produced most frequently by authors who were from ages 40 to 44 inclusive. This statement applies to the publication of books that are placed most often on "best books" lists. However, when the various types of literature are considered separately the peaks of productivity are found to vary rather widely.

GALILEO AND SCIENTIFIC HISTORY

By Professor LANE COOPER

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QUITE unexpectedly to me, some heat appears to have been aroused by a little book of mine called "Aristotle, Galileo, and the Tower of Pisa," a volume published last year by an emergent University Press of Cornell University. The object of the book was to present the evidence concerning the alleged experiment or experiments of Galileo about the year 1590 from the tower of Pisa in public demonstration of an alleged mistake by Aristotle with regard to falling bodies—namely, the supposed misstatement by him that, in falling, heavier bodies will move faster in proportion to their weight. The evidence, so far as it appears in languages other than English, is presented in translation and also in the original tongues; and, in particular, the requisite passages from works of Aristotle, passages which have hitherto not been confronted with the evidence from Galileo's writings, or *vice versa*, are made accessible to the kind of reader I had in mind—the teacher, say, of mathematics, physics or the like, or the reader of "scientific history" who has no ready access to the ancient and the modern foreign languages or at all events none to the original sources of this tale concerning an ancient Aristotle and a modern Galileo.

The passages I thought desirable to translate from the Italian of Galileo's first "Dialogue Concerning Two New Sciences" (1637) and the Latin of his earlier treatises "De Motu" (about 1590) are duly recorded and opened for the reader in my book. But in *Nature* (London), January 4, 1936, pp. 8–9, Professor A. S. Eve calls attention to passages from Galileo's dialogue which might well have been quoted in my volume. I should gladly consider including some part of the added quotations if another edition were called for, but must now remind the reader, first, that the passage on falling stones in the dialogue of 1637 echoes a much earlier passage of "De Motu" (see my page 50) in which Galileo about the year 1590 ironically talks of what would happen if two spheres of lead were let go from the moon; and, next, that the "Sagredo" of the dialogue, who says he has "made the test" with falling bodies and who represents views entertained by Galileo, is not to be identified with him. Galileo is referred to in the dialogue as an authority outside of it, "our Academician" (*cf.* the Edizione Nazionale of Galileo's Works, Volume 8, page 54). "Sagredo" bears the name of an actual person, a friend of Galileo. He is a Venetian. Mr. Eve says, "It is certainly disconcerting to find Sagredo altering the height from 100 to 200 cubits," that is, from the 100 cubits of "Salviati," the other interlocutor who holds similar views on the fall of bodies from a height; we may note that whereas the tower of Pisa is 178 feet high, the well-known tower at Venice is, or was, 323. If we are to go behind the imaginative dialogue in search of historical fact, should we not argue that the historical Sagredo at Venice, and not Galileo at Pisa, had in this instance "made the test"? It is better not to press the point; we may yet find the utterances of "Salviati" and "Sagredo" more vulnerable than some have thought. Contrary to the statement of "Salviati," Aristotle does not say that "an iron ball of one hundred pounds falling from the height of one hundred cubits reaches the ground before a one-pound ball has fallen a single cubit." He does not use that kind of language at all. He does not say fall or ball or one hundred or cubits or anything of the sort; he states general laws of motion, using the Greek words to express the concepts of magnitude, shape, weight and proportion, and the letters of the Greek alphabet as we use A, B, C, D, rather than the quantities of arithmetic; and it is important to study what he does say before supplying any of his generalizations with an example. "Salviati" goes on. "I say they arrive at the same time." That is not true, as he immediately shows: "You find, on making the experiment, that the larger outstrips the smaller by two finger-breadths, that is, when the larger has reached the ground, the other is short of it by two finger-breadths; now you would not hide behind these two fingers the ninety-nine cubits of Aristotle."

Behind those two fingers there are said to lurk laws, about the movement of heavier bodies through viscous media, out of which the qualified student of physics can make some defense of Aristotle, considering his time and circumstances, in his statements about lightness and weight, media and motion. Aristotle says that the heavier body moves faster over an equal space than the lighter; that they move differently in proportion to their magnitudes or sizes and the density of the medium. As he expresses the proportion, it does not necessarily mean either ten to one, or a hundred to one, though it has been taken to mean both. Can it be both? After all, "Salviati's" *two fingers* and "Sagredo's" *span* express a proportion. And what about the ratio of 120 to 395 which is noted at the end of the present article?

Aristotle says that a moving object cleaves the medium either by its shape or by the impulse which the body that is carried along or is projected possesses; the assertion sounds reasonable in these days of Big Berthas and streamlined cars and airplanes. He says that the downward motion of a mass of gold or lead or of any other body endowed with weight is quicker in proportion to its size, a statement to which we shall return, for a diving airplane is clearly a body endowed with weight. He says that would not be true in a void; the Greek word is commonly taken to be the equivalent of our "vacuum"; it surely implies the absence of any medium to retard the moving body. Professor E. K. Rand tells me that Aristotle's reasoning on the conduct of objects of different weights in a vacuum brought about a change in the atomistic theory: "After his remarks it was no longer possible to imagine that objects of different weights falling in parallel lines in a void would ever catch up with one another." Aristotle's utterances as they have just been outlined are in support of his contention that the void, a perfect vacuum, is impossible. They have been assailed as if they were main, and not subsidiary, positions with him. They are supplied with chapter and verse in my book; and I hope that some master in physics will study them there or in Aristotle's works, not with respect to the tower of Pisa, but, let us say, with respect to the fall of a dummy man from mid-air out of a diving airplane. Since Aristotle does talk in "De Caelo" of letting something go from mid-air, let us say it might mean from a height of 18,000 feet.

As for Mr. Eve's citation to show that Galileo knew what he was criticizing, there is ample evidence that Galileo read Aristotle. On this head, I resisted the temptation rather to quote extensively from the early treatise "De Motu," which belongs to Galileo's interval of teaching at Pisa, and reveals his study of Aristotle, anticipating his later attacks, and also to go into the question whether he consulted the "Physics" and "De Caelo" in Greek. Viviani says that Galileo took up the study of Greek in youth. Since he wrote Latin, however, Galileo doubtless often followed a procedure not without a parallel in our day, and, for economy of time, mainly referred to the works of Aristotle in quite available Latin translations.

A harsher critic, the learned Aldo Mieli, in a recent number of *Archeion,* pages 303–7,[2] takes my book to task for an ignorance of physics which it freely admits. Since I am supposed to be a student of language and literature, my personal interest lay in tracing the growth of a myth from a posthumous story about "repeated experiments" said to have been made in public by Galileo as a young teacher at Pisa, yet never referred to by him or any one else in all the controversies of his career; its growth, that is, into the now widely accepted tale that by a single dramatic experiment he worked a revolution in physical science. No such miraculous change has been brought about in one day in any age by Galileo or another. Signor Mieli is perhaps unduly severe through a misunderstanding of some parts of the book which were hopefully meant to be humorous, but have fallen without prosperity on a Continental ear. But, apart from that, in Italian eyes of to-day it no doubt was a mistake to call a German, Wohlwill, the best authority on Galileo's experiments at Pisa, or to join with him and Hugo Dingler in finding something odd about a passage where Galileo, at the approximate date, 1590, of the alleged experiments, does speak of his observation of falling bodies; where in fact he says he has "often tested this"—namely, that, in free fall, *wood starts off faster than lead!* It seems to have been a queer traditional notion that certainly did not disappear as the result of "experiment" or "experience" by Galileo. The Latin word *experientia* embraces both concepts. Can the passage on wood and lead rightly be used in support of the tale about the alleged experiments from the leaning tower?

Favaro so uses it in an article on the credibility of Viviani's Life (our source for the story of Galileo and the tower), in *Archivio storico italiano,* anno 73 (1915), Volume 1, pages 340–3, where he attacks the position of Wohlwill. Bending to the criticism of Mieli, I cheerfully direct attention to this article, but must call attention also to Favaro's article, not mentioned by Mieli, upon "some inexactitudes" of Viviani, *ibid.*, anno 74 (1916), Volume 2, pages 127–50. Much as we respect the learning and devotion of Favaro, chief editor of the great National Edition of Galileo, we still recommend the scepticism of Wohlwill and Dingler on the point at issue The credibility in the main of Viviani's Life does not depend upon our accepting one tale with an inherent improbability—that Galileo *repeatedly* made experiments from the tower in the presence of *all* the teachers and students at his university.

If reputable authors of our generation accept this tale one from another, repeat it with absurd variations, take words from a dialogue of Galileo for the words of Aristotle and never look into Aristotle to see what he says and in what connection, how are we to think of the critical standards of Viviani in the year 1654? More than a century later, the competent William Bartram, American botanist and zoologist, can thus describe one party in an alligator-fight ("Travels," 1794, page 116): "His plaited tail brandished high, floats upon the lake. The water like a cataract descends from his opening jaws. The earth trembles with his thunder." Was his tail brandished high, or did it float? Aristotle in his "Poetics" notes how a story grows. He says that people like to add interesting details in the belief that it will gratify the listeners. Lives of Galileo and histories of science bear him out.

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[2] The pages, not the whole number, have reached my publisher.

The end of the present article may likewise illustrate that impeachment.

Mr. Eve remarks: "No doubt Lane Cooper is correct in saying that Galileo was flogging a dead horse, and that many had already attacked the rash statement of Aristotle." And the passage from "De Caelo" about "the downward movement of a mass of gold or lead, or of any other body endowed with weight," that it "is quicker in proportion to its size," he calls "very suggestive of [Aristotle's] erroneous view of falling bodies." Now my book tells of persons both before and after 1590 who are said to have made the like test, though I was not bent on mentioning any after 1606 save Coresio and Renieri; Eiffel is said to have experimented with all sorts of objects from his tower 984.25 feet high. I did not talk of "a dead horse," nor call any statement of Aristotle's "rash," nor think that what he says about the downward movement even of gold, to say nothing of *any other body endowed with weight,* would be erroneous if the medium through which it moved were dust and not air. But in my book I did go too far in holding that it is quite erroneous with respect to air, or such is my present notion in my very imperfect knowledge of physics. When writing my book, I believed with Galileo, Gregory, Hart and many another, that if you went to the top of the leaning tower and dropped a ten-pound weight and a one-pound weight, or a hundred-pound weight and a one-pound weight, when they reached the ground together, or nearly so, it would prove Aristotle wrong with respect to the downward movement of bodies through air. I went along with the experts who would let a teacher of English believe that it made no difference whether the proportion between the bodies was ten to one or one hundred to one, whether the tower was 100 cubits or 200 cubits high, whether the bodies hit the ground simultaneously or with a slight interval in the times of alighting and whether that interval was two fingers or a span. I do recall being troubled by a discrepancy between Aristotle's use of algebraic symbols in "De Caelo" 3.2 and the subsequent reduction of them to arabic numbers. Now I wish to leave the question in the most capable hands, and refer all readers to the section entitled "Aristotle's Dynamics," pages 26–33, in the admirable edition of Aristotle's "Physics" by W. D. Ross, Oxford, 1936, who says (page 29):

> In fact, having observed accurately that motion through a denser medium is slower than through a rarer one, he makes the natural enough mistake of supposing that velocity and density *ceteris paribus* vary inversely; failing to notice that the relation which connected them might be more complex than that of inverse proportion. A better mathematician might, even in the absence of evidence, have noticed the possibility of this.

The same writer mentions the correspondence of Hardcastle and Greenhill in *Nature* (92: 584–5, 1913–14; 93: 428, 1914) on the terminal velocity of projectiles, and on the bearing of that problem upon the statements of Aristotle and Galileo. These letters came to my attention after I had virtually finished the present writing; so also an unverified reference to motion-pictures of raindrops, with the tempo of the pictures slowed so as to show how the larger and heavier drops pass the smaller and lighter in mid-air.

Meanwhile are they who, in the face of weak evidence, still suppose that a theatrical Galileo might well have ascended the tower, after due advertisement, to perform modern experiments with free fall before the mob—are they really honoring that great and good man? If Stokes and Rayleigh had lived in Galileo's day, would either have lent himself to a display of the sort? As a person necessarily unversed in the latest physical research, I yet humbly ask what significance should attach to an episode like that? Since publishing my book, I have heard of something mentioned above, namely, laws respecting the movement of heavier and lighter bodies through viscous media, one of which laws apparently could be tested for "the downward movement of a mass of gold or lead, or of any other body endowed with weight," through air, somewhat better if you took the objects up in an airplane and dropped them from a point several miles high than if you dropped them from any celebrated tower in Italy. For me, so far as I can understand the law, it goes better with the statements of Aristotle than with the story of Galileo; better, for example, with the passage about "a bit of earth let loose in mid-air"—"the more there is of it the faster it moves." Of course it is fun to feel wiser than Aristotle, though the fun commonly entails a loss of historical perspective. It is also fun to go faster than anybody could in the days of Galileo. Herewith we reach our proportion of 120 to 395, and our terminal velocity.

Our experimenter shall now be the late Mr. Collins, who wrote for *The Saturday Evening Post* (Philadelphia) of February 9, 1935, and knew about free fall from personal experience. His article, here quoted by editorial permission, is entitled "Return to Earth, or Diving Ten Thousand Feet Straight Down." We read (page 51):

> I did five speed dives first. These were to demonstrate that the ship would dive to terminal velocity. Contrary to popular opinion, a falling object will not go faster and faster and faster and faster. It will go faster and faster only up to a certain point. That point is reached when the object creates by its own passage through the air resistance to that passage to equal in pounds the weight of the object. When that point is reached, the object will not fall any faster, no matter how much longer it falls. It is said to be at terminal velocity. A diving airplane is only a falling object, but it is a highly streamlined one, and therefore capable of a very high terminal velocity. A man falling through the air cannot attain a speed greater than about a hundred and twenty miles an hour. But the terminal velocity of an airplane is a lot more than that. . . .
>
> I went to eighteen thousand feet for the final one. . . . I eased the throttle back, rolled the ship over in a half roll, and stuck her down. I felt the dead, still drop of the first part of the dive. I saw the air-speed needle race around its dial, heard the roaring of the motor mounting and the whistle of the wires rising, and felt the increasing stress and stiffness of the gathering speed. I saw the altimeter winding up—winding down, rather! Down to twelve thousand feet now. Eleven and a half. Eleven. I saw the air-speed needle slowing down its racing on its second lap around the dial. I heard the roaring motor whining now and the whistling wires screaming, and felt the awful racking of the terrific speed. I glanced at the air-speed needle. It was barely creeping around the dial. It was almost once and a half around, and was just passing the three-eighty mark. I glanced at the altimeter. It was really winding up now! The sensitive needle was going around and around. The other needle read ten thousand, nine and a half, nine. I looked at the air-speed needle. It was standing still. It read three ninety-five. You could feel it was terminal velocity. You could feel the lack of acceleration. You could hear it too. You could hear the motor at a peak whine, holding it. You could hear the wires at a peak scream, holding it. I checked the altimeter. Eight and a half. At eight I would pull out.

IRRATIONAL RHYTHMS

By Dr. JAMES B. SHAW

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FROM the earliest times of history number has fascinated man, and he has endowed it with mystical properties. Three, five, seven, ten and other numbers have had potencies which man has tried to use. Even to-day numerology has its devotees, and among them many who are supposed to be enlightened, and not all the devotees of mystical number are aware of their religion. How number came into the consciousness of man no one knows. It is quite possible it was forced into his consciousness by the rhythms of his daily life. The pulsing of his heart after a long chase, the rhythms of his steady walk home, the beat of waves on the shore, the succession of day and night, the arrangement of the petals of flowers, the phyllotaxis of leaves on a stem—these and many others would inevitably be noticed and from them would come the idea of the integer and the ratio. After he learned how to add, subtract, multiply and divide he would have noticed that his result would always be within his list of numbers. After the invention of negative numbers he would not be hampered in his subtractions, and now he would have a complete field of number, the rational numbers, which would possess an endless system of rhythms. Every prime number would start a new set of ripples in the currents of his intelligence. In the course of time the classification of integers and ratios was completed. Thousands of theorems have been found for them, and occasionally even to-day some one prints a new set of remarkable relations for certain numbers.

However, as early as the time of Pythagoras it was known that there were numbers not in this list. If we lay off the side of a square on the diagonal, and then the remainder of the diagonal on the side, and so on, we will never find a small segment left over which will measure those before exactly. It is easy to see this is the case, for if we lay off the side on the diagonal and then draw from this point a perpendicular to the diagonal to meet the side, it will cut off the proper segment, and we then have again a side and a diagonal of a square to compare. That is, after two steps we are just where we started. A phyllotaxis like this would go around and around, but never would the terminal point be just over the initial point. Pythagoras knew of other irrationals, and they wrecked his philosophy, for he thought the universe could be expressed in terms of ratios and integers. Even to-day there are those who say the universe is simply the incarnation of mathematics.

In the flow of the centuries numerous irrational numbers were found, and as the study progressed they became more and more complicated. A wilderness of number sprang up, and there seemed to be no basis for classification of them which was not artificial. However, early in the last century, there appeared in France a turbulent young genius named Évariste Galois. He had a stormy career, since he mixed up in the politics of the day. He was a great annoyance to his instructors, for he had too many original ideas, which they did not understand, and they were afraid of him. It is said that one day he heard of geometry. He at once went to the library, found the treatise of Legendre, read it through in the afternoon and threw it down with the remark that it was so simple there was nothing to it. He died in 1832 at the age of scant twenty-one, from a shot in a duel. The duel was evidently a frame-up of his enemies. The night before, he sat up all night writing out what he had found out about algebra, and left a thin memoir for a friend to publish. This has been the subject of much study ever since, and has been the spring from which have come many deep investigations. One of the important things in it is the basis for classifying irrational numbers that come from algebraic equations, and Galois also discovered the essential rhythms they possess, so that the wilderness has turned out to be really a landscape of wonderful designs. We will look at a simple example of what Galois was talking about, in order to understand what he said.

Suppose we study the irrational number which may be written in the form:

$$R = \sqrt{(2 + \sqrt{2})(3 + \sqrt{3})}$$

This is an answer to the equation

$$x^8 = 24x^6 - 144x^4 + 288x^2 - 144.$$

There are also seven other answers as follows: S, which is found by changing in R the sign in front of $\sqrt{2}$; T, which is found by changing the sign in front of $\sqrt{3}$; and U by changing both these signs. Then the other four are $V = -R$, $W = -S$, $Y = -T$, and $Z = -U$. We shall see that there are very remarkable properties connecting these eight numbers. In the first place, we can find that S is expressible in terms of R as a polynomial, thus:

$$24S = -R^7 + 20R^5 - 60R^3 - 24R.$$

Likewise we have

$$12T = R^5 - 18R^3 + 36R$$

and

$$12U = R^7 - 22R^5 + 102R^3 - 120R.$$

Then the other four would be found from these by merely changing all signs. This is very remarkable, because usually if we solve an equation and find all the answers, we can not express them as polynomials in a single one. But, what is still more remarkable, if we start with S in place of R, or with T, or with U, these same polynomial forms, written out in terms of S or of T or of U, will also give the entire set of numbers. In other words, these polynomial forms have the property that whichever number we start with, they will furnish all the numbers. In such a situation we call the set of eight numbers *conjugates*. To go further, if we write out the polynomial form for S in terms of S instead of R, and reduce the result, we would be surprised to find that the final result is $-R$. That is,

$$24R = S^7 - 20S^5 + 60S^3 + 24S.$$

The same will be true for each of the other forms, that is, if we change the one for T by writing T instead of R, and reducing, we shall find in the end that it is also $-R$. The form for U written out in terms of U instead of R will also give, when reduced, $-R$.

But we are not done with the problem. Suppose we write the form for S in terms of T instead of R, what will be the result? The answer is that when reduced it gives U. On the other hand, if we write S for R in the form for T, it reduces to $-U$. And now we see what else to look for. If we write U in place of R in the form for T we shall find upon reducing it that we have S. If we change this about and put T in U for R we shall have $-S$. Finally, if we put S for R in the form for U it reduces to T, and if we put U for R in the form for S it reduces to $-T$. This possibility of writing in any one of the four letters is certainly something we might not expect at first. We see that putting in the other four will merely change all signs, for there are only odd powers of R in the forms, and the other four letters are the negative numbers for the first four. Since the result of starting with R, constructing any polynomial and then substituting in it some other letter for R, comes out one of the eight letters, and is therefore a polynomial in R, we evidently have a closed set of processes. The performance of any one and then writing in the result of some other gives us one of the processes. We will see this better perhaps if we write out the things we have so far found out in a small table of the effects of the eight processes. For simplicity we will call the construction of the polynomial which gives S, by a single letter I. Also the process which gives T we will call J, and that which gives U will be K. Then we will have to have a label for the statement R = R, and this will be E. We will also have to write for the process giving V, – E; for that giving W, – I; for that giving Y, – J; and for that giving Z, – K. Then we have the table:

E	I	J	K
I	– E	K	– J
J	– K	– E	I
K	J	– I	– E

This means, for instance, that the effect of doing the process J after we have done I will be – K, or J after K will be I. That is, if we first get S then put it in the polynomial for T we will have – U or Z. Since this table gives also the products of the numbers used in quaternions called 1, i, j, k we call it a quaternion table. We say that the polynomials above form a quaternion group. And we call the original equation a quaternion equation, and the numbers R, S, . . . Z, we say belong to a quaternion field. We mean by that to say that the numbers arising from adding, subtracting, multiplying or dividing these eight numbers will always be a polynomial in R and therefore equally also a polynomial in either of the eight. In short: the rational numbers compounded with any one of the eight numbers R, S, . . . Z, will always give a number which can be written rationally in terms of R or S or T, etc. Moreover, if we construct any polynomial whatever in terms of R, there will be similar polynomials in terms of S, T, etc., and the numbers they represent will be a set of conjugates, either eight different numbers or four different or two different or all the same number.

We are not done, however. For if we go back to R we see in it $\sqrt{2}$, and $\sqrt{3}$, and we might inquire: Are they expressible in terms of R and then in terms of any other of the eight letters? The answer is: Yes. We find indeed that

$$24\sqrt{2} = -R^6 + 20R^4 - 60R^2.$$

Also

$$12\sqrt{3} = R^6 - 21R^4 + 84R^2 - 72$$

We may further put in

$$24\sqrt{6} = -R^6 + 24R^4 - 132R^2 + 144.$$

This means now that any combination of rational numbers, these square roots, and any of the eight numbers may be reduced to a polynomial in terms of R, and therefore in terms of S or the others.

We are now in a position to say that as far as rational numbers and the three square roots above are concerned, all their combinations by the four processes of addition, subtraction, multiplication and division, and their combinations with the eight numbers which are the quaternion conjugates never arrive at anything but rational numbers and powers of R, or of S, · · · . That is, in brief, R defines a Galois field of the quaternion type, every number in it being a polynomial in R. An equation like the one we started with is called a *normal equation* and the field a *normal field*. What Galois said amounted to the proposition that all irrational numbers arising from algebraic equations are made up of numbers belonging to normal fields. The entire list of algebraic irrationals, then, is classified into the types coming from the normal fields. The first problem is to find out what are the normal fields and what kind of equations are normal equations. For instance, there are but five types of fields, each of which has eight conjugates. The quaternion type we have just studied is one of the five. The normal equations for the other four are not complicated. For a field with a prime number of conjugates there is but one type, the cyclic. That means that if we form the polynomial from R for S, and then keep substituting in it the new conjugate, we shall come back at last to a form which reduces to R. For an example suppose

$$R^3 = 21R - 35,$$

then we will have

$$S = R^2 + 2R - 14,\ T = S^2 + 2S - 14,$$
$$R = T^2 + 2T - 14$$

For each type of normal field there will be a set of processes similar to I, J, K, $\cdots$ which when combined will give all the conjugates. A table of their combinations can be made out as we did above. Such a table gives us the results of combining the various processes that make up the Galois group belonging to the field. For each normal field there is a group. When we study the groups by themselves we find that for a given number of processes N, there is possible only a finite number of groups, but we do not yet know whether in every case there is a field for any given group. For the possible groups of order 8, we do have normal equations, however, and we would expect any group to have a field belonging to it. If the group is studied as a problem in combinations we call it an abstract group. For every abstract group the corresponding Galois groups will be endless, but all with the same structure. We find then an underlying design in the order that gives us the various combinations. And since all the conjugates may be considered as the various numbers belonging to a single entity we have unity in the structure of a normal field. In fact, the single number is the one we call the hypernumber which is the complete root of the equation. We can not enlarge on this.

There is another feature which we will notice, since it explains something further which Galois said. If we arrange the terms of the equation above properly we may write it in the form

$$(x^4 - 12x^2 + 12)^2 = 6(2x^2)^2.$$

This enables us to see that if we use not only rational numbers but the $\sqrt{6}$, then we can take a square root of each side and the result is an equation of the fourth degree. It may be solved as a quadratic giving R in a square root form which has integers and $\sqrt{6}$. In this form we may construct U in terms of R and we will find the polynomial form is cyclic of order 4. So also we might write the equation in the form

$$(x^4 - 12x^2 + 36)^2 = 2(6x^2 - 24)^2.$$

If we are allowed to use $\sqrt{2}$, this also reduces to a fourth degree equation from which we can find R, and then S would be given by a polynomial which is again cyclic. And if we write the equation in the form

$$(x^4 - 12x^2 + 24)^2 = 3(4x^2 - 12)^2$$

we could arrive at a cyclic quartic by using $\sqrt{3}$. So we see what Galois meant when he said that if we could use rational numbers and another number properly chosen from an irrational field, we would be able to reduce the degree of the equation.

We will now see what happens when we perform the eight processes in turn upon the entire set of eight conjugates. We can see this best in a series of diagrams. We will use E to represent the original diagram, then I the one produced by changing each letter according to what the polynomial I gives, likewise for J, and K, and we will write these four in the center of the figures. We have then the four diagrams:

Y V
W Z
E
U S
R T

Z W
R T
I
Y V
S U

R Y
U W
J
S Z
T V

S Z
Y R
K
V T
U W

The reader will find it interesting to discover the simple rule for shifting the letters. As a hint they change in pairs, always the same way. The effect of the processes − E, − I, − J, − K will be shown in the following diagrams:

T R
S U
−E
Z W
V Y

U S
V Y
−I
T R
W Z

V T
Z S
−J
W U
Y R

W U
T V
−K
R Y
Z S

The reader will find that each of the eight processes when repeated will ultimately bring back the original diagram. E of course will always give it. − E has to be used twice. The others four times around will come back to E. These are eight positions of eight dancers, which in the various shifts could be called the Quaternion Dance. There is a similar diagram for every normal field. We could also look upon these diagrams as representing flowers with the petals of different colors. A flower would belong to the field only if the petals were arranged in one of the possible ways. In the case above the petals would have eight colors, and just eight possible arrangements, if it bloomed in the Galois quaternion field.

What Galois saw and reported was this new type of beauty: the beauty of the irrational. It is remarkable that the vast array of algebraic irrationals can be reduced to polynomials in terms of any selected primitive number from each of the different Galois number fields, and that the number of possible fields is after all not so very large, if we do not consider equations of too high a degree The list of normal equations is equally not so very large. Whatever algebraic equation we have to solve, the problem amounts to finding what normal equations we need in order to have the necessary fields from which come the irrationals in the final expression of x. For instance, to solve a quintic may require square roots and then numbers from a complicated field of order 60, called an *icosahedron field.* There are 60 conjugates, none expressible in radicals, but from any one all of them may be found rationally. Will there ever be a Galois for the irrationals like π which are not algebraic? The study of automorphic functions is a step in the right direction, and in series of orthogonal functions we make progress. So we may predict there will be another Galois for these irrationals. Let us hope for him a life which is not tragic.

SOLUTIONS UNDER HIGH PRESSURE

By Dr. R. E. GIBSON

GEOPHYSICAL LABORATORY, CARNEGIE INSTITUTION OF WASHINGTON

If I take some table salt and mix it with water, the salt, as you all know, will disappear and I shall be left with something that looks like water but is not nearly so pleasant to drink—in other words, a salt solution. You have all performed this experiment and may have wondered what became of the salt. For several centuries chemists have exercised their minds over this question, but they have not found a satisfactory answer. In the process, however, they have thrown considerable light on the nature of matter and incidentally of our own mechanisms—we shall not, however, dwell further on this point.

Factors Affecting Solubility

You know, furthermore, that if I take enough salt I shall reach a state when no more will disappear or dissolve and the salt solution will be "saturated." The amount of salt which goes into the saturated solution is called its solubility. Different substances have different solubilities in water or other liquids. You also know that the solubility of a substance changes with temperature. If, to make an eye lotion, we dissolve boric acid in boiling water we know that, although the solution is perfectly clear when hot, it will deposit a mass of crystals of boric acid after it has cooled. The solubility of boric acid in hot water is much greater than in cold water.

What perhaps you do not know is that if I take a saturated solution of a substance, keep its temperature constant and squeeze it with a very high pressure I shall be able to make the solution either deposit crystals or dissolve more. Generally speaking, the former process will take place if I squeeze the solution hard enough. It is to this change of solubility with pressure that I wish to call your attention, telling you briefly how the subject is studied, what advances have been made and what consequences of general interest the work may have.

Solubility in Relation to Pressure

Prior to 1931 very little was known about changes in solubility under pressure. A few workers had made good observations, but the number of solutions studied was small and the pressures used comparatively low, not exceeding 1,500 atmospheres or bars, *i.e.*, about 22,500 lb./sq. inch.

In 1931 Dr. L. H. Adams of the Geophysical Laboratory published the results of a systematic study of the solubility of common salt (sodium chloride) in water up to pressures of 16,000 atmospheres (240,000 lb./sq. inch). These were the first experiments of their kind ever made and were followed by investigations of the solubility of potassium sulfate, ammonium nitrate and potassium iodide over the same wide range of pressures. I shall not enlarge upon the details of these researches but will merely emphasize that each of these four substances behaved in a seemingly highly individualistic way as regards its change of solubility with pressure.

As will be seen in Table I, no features common to the behavior of all the four salts were immediately obvious. This was somewhat disappointing for, as I shall discuss later on, one of the objects of this work was to discover some general

TABLE I

SOLUBILITY OF DIFFERENT SOLIDS IN 100 GRAMS OF WATER AT VARIOUS PRESSURES AND 25° C.

Substance	Weight of solid dissolved in 100 grams water				
	Pressure: Atmospheric	1,000 bars	4,000 bars		10,0 bars
Sodium chloride .	35.9	36.2	38.3	37.8	36.9
Potassium sulfate	12 1	16.0	19.5	18.2	16.0
Ammonium nitrate	208 9	161.0	89 6	59.5	42 3
Potassium iodide.	148.0	152.0	161.0	172.0	181 0

laws that might hold for changes in solubility in all solutions under pressure. Further study showed, however, that general features common to the behavior of the solutions of all these and of other salts were indeed present, but they lay below the surface and had to be dug out.

How was this done? In the first place, I should say that although it is possible to determine directly how much of a given solid water or any other liquid dissolves under very high pressures, it is not always convenient or necessary to do so. The well-established science of thermodynamics shows us that in order to determine changes in solubility with pressure the only measurements we have to make under pressure are those of volume changes—a relatively simple thing to do. Let us, therefore, consider for a moment how the volumes of solutions change under pressure.

METHOD OF PROCEDURE

If we take, say, water, put it into a strong cylinder and force a piston into the cylinder we shall generate a very high pressure and at the same time the water will shrink a small amount. This small shrinkage is called the *compression* of the water if the original volume is one cubic centimeter. If now, to the water we add some solid, say common salt, we shall find that, for a given pressure, the compression of the solution is less than that of the pure water. The difference is very small but highly significant, and the measurements must therefore be made with great precision. The stronger the solution the less does its compression for the same rise of pressure become.

These small differences between the compressions of pure water and those of solutions of different concentrations up to the saturated solutions are all the measurements we need under pressure, and, when these are combined with quantities which are measured at ordinary pressure, we obtain the solubility of the substance in water at different pressures. You will see, then, that if we find any law about how the volumes of solutions change with pressure we may immediately extend it to a slightly more complicated law about how the solubility of the dissolved solid changes with pressure.

LAW GOVERNING CHANGES IN VOLUME WITH PRESSURE

For solutions in water we found such a law—it had been proposed over 40 years ago by Gustav Tammann—a brilliant idea which had been tested with the fragmentary data then available but not developed. This hypothesis suggested that water mixed with a solid (in a solution) behaves like water that is under a pressure greater than the external pressure, as if the salt pulled the water molecules closer together than they normally are.

When this simple hypothesis is developed we find that, if we know the compressions of water over the whole pressure range from 0 to 12,000 atmospheres (180,000 lb./sq. inch), and, if we determine from measurements at low pressures the internal pressure that the salt appears to exert on the water, we may calculate the compressions of any of the solutions over this whole range of pressure. When the results of these calculations are compared with experimental observations we find excellent agreement.

To summarize, therefore, we may say that it is in general possible to calculate the compressions of solutions of solids in water up to the highest pressures under which the solutions will exist simply from observations at low pressures. I should emphasize, however, that had it not been for the experiments on volume and solubility changes in solutions made at the Geophysical Laboratory we should still be in doubt as to the validity of Tammann's hypothesis and any conclusions based thereon would be subject to suspicion.

Returning to the main subject of this article, namely, the influence of high pressure on the solubility of a solid, we may state that this influence is in general larger than was previously expected and that in the case of solutions in water it may be predicted by the method I have outlined from considerations which involve only measurements at low pressures. I have sought to extend the results to solutions in solvents other than water and have found the same conclusions to be true, but this work is still in progress.

While the results I have just outlined are of some interest in themselves, I must confess that their main importance lies in their being one step towards the elucidation of larger problems. They have a direct bearing on the problem of the nature of liquids and on the forces of attraction and repulsion which exist between the molecules of solids and liquids, an important subject which unfortunately can not be elaborated in this short article.

THE PROBLEM OF ROCK FORMATION

This work was undertaken primarily to provide a physicochemical basis from which to attack the problem of rock formation under pressure. Let us return momentarily to the boric acid solution. We started with a hot, clear solution: it cooled to room temperature, became supersaturated and deposited solid boric acid. If we had cooled it further the water itself would have frozen and we should have been left with a solid mass of boric acid and ice.

It is now generally accepted that the earth was once a liquid like the boric acid solution, only much hotter and infinitely more complex. As it cooled, it deposited complicated masses of crystals until practically all was solid, giving the rocks with which we are all familiar. In principle, then, the formation of rocks resembled the crystallizing of the boric acid solution, with this difference that, whereas the pressure in the boric acid solution was small, the pressures miles down inside the earth where rocks either crystallized or whither they sank immediately after solidifying are enormous, being measured in tens of thousands of atmospheres. If, then, we are to understand the way in which rocks were formed we must know not only the solubility of solid minerals in molten silicates at high temperatures, but also how this solubility is influenced by high pressures. It is possible to examine the behavior of minerals under high temperatures and pressures—indeed, such work is being done at the Geophysical Laboratory and elsewhere—but the technique is extremely difficult and very slow.

Modern scientific theories of matter give encouragement to the belief that, if we find regularities in the behavior under high pressures of simple solutions that can be examined at room temperature, the results may be modified and applied with success to other solutions at higher temperatures. With this in mind we are attempting to prepare a background of knowledge of the behavior of solutions under pressure in the way I have described to you, but, while I believe that this background will prove of fundamental importance in solving some of the problems of rock formation, I do not want to give you the impression that this application of the results is immediately possible. Much more work will have to be done.

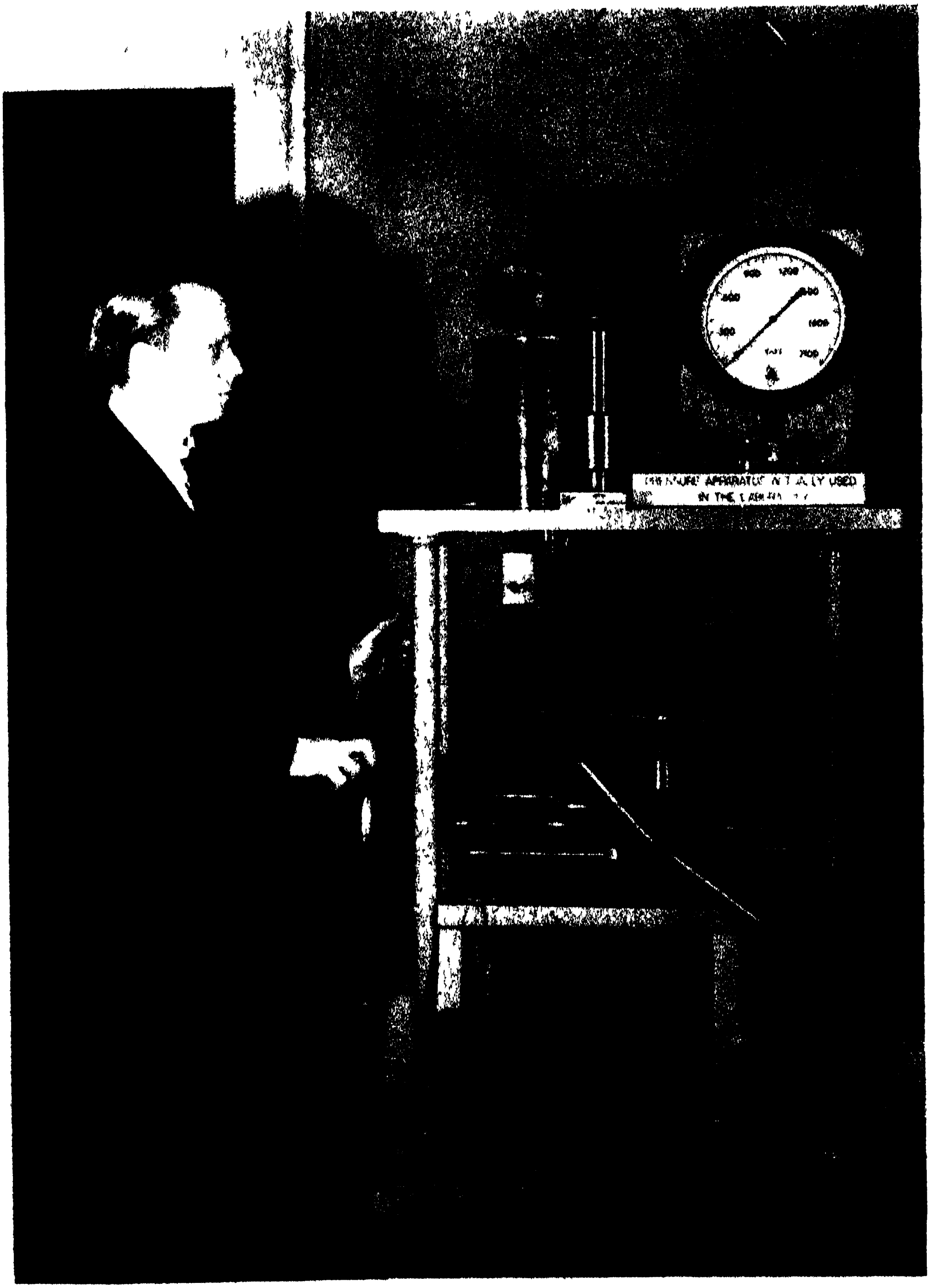
THE TEMPLE OF SCIENCE

The advance of our understanding of nature may be likened to the building of a magnificent edifice, such as a cathedral; we are building an intangible temple of organized knowledge. All the facts, like the building stones, must be quarried from nature with much labor; they must be hewn and polished, sculptured and fitted together to form the various members of the building. By the genius of some master mind or architect, these members are gathered into a beautiful and stable structure, which not only delights the mind but withstands the onslaught of time.

The building of this temple of science proceeds steadily, but only occasionally does its progress catch the eye or appeal to the popular imagination. A new or startling type of fact wrested from stubborn nature arouses our interest, we catch to some extent its importance, above all it arouses our curiosity. When a tower or some outstanding feature of the building is completed, when some all-embracing theory such as the theory of relativity links together many members of the structure, the world at large looks on with interest and amazement. Between the new types of facts and the finished tower there is a large gap. The tower rests on foundations hidden from the average person. If the structure is to stand the test of centuries, these foundations must be systematically and carefully laid, each stone must be carefully examined, hewn and fitted accurately into place. This part of the work of building is what distinguishes modern science from ancient philosophic speculation.

In the finished temple of science the work I have just described may form one of the courses of blocks deeply hidden in the foundations of a tower or buttress. I have tried to show you how the stones were quarried, polished and fitted together.

And why should we work to build this non-material temple of organized knowledge, why did Andrew Carnegie, whose one-hundredth birthday we have just celebrated, give so liberally of his substance towards its advancement? Surely it is to the end that ignorance and superstition at least may not impede us, our children and the generations yet unborn from living richer, freer and grander lives.



THE PRESSURE APPARATUS

WHICH ENABLES THE INVESTIGATOR TO RECORD ACCURATELY THE BEHAVIOR OF SOLUTIONS UNDER PRESSURES THAT ARE COMPARABLE TO THOSE IN NATURE WHEN ROCKS ARE FORMED.

—From a painting by Seymour Thomas

ARTHUR AMOS NOYES

THE PROGRESS OF SCIENCE

ARTHUR AMOS NOYES, AN APPRECIATION

THE death of Arthur Amos Noyes, which occurred at Pasadena on Wednesday, June 3, removes from the scene one of the outstanding figures of American chemistry during the past half century. His scientific career covered the entire period from 1886 to 1936. An evaluation of Noyes's contribution to American chemistry can be made only in the light of the history of chemical science in America during that time. When A. A. Noyes was graduated from the Massachusetts Institute of Technology in 1886, chemical research in America was almost unknown. It is true that Remsen's Laboratory at the Johns Hopkins University had then just recently been founded and an opportunity was there afforded Americans to acquaint themselves with research methods in chemistry, an opportunity of which a number of eminent American chemists took advantage But, by and large, chemical research in America was confined to a very few individuals who struggled on under highly disadvantageous conditions and whose work attracted but little attention among their contemporaries. American universities at that time did not consider that the fostering of research was one of their primary purposes.

Although Noyes's early contact with chemistry lay in the fields of analytical and organic chemistry, fields, moreover, which he continued to cultivate—particularly, the former—throughout the rest of his life, he was innately a physical chemist. Although he was not especially trained in physics and mathematics, he had a natural physical sense which enabled him to analyze problems from the physical point of view, to devise experiments to answer crucially important questions and to carry out these experiments with a precision which went beyond that of other experimenters engaged in the same fields. Coming under the influence of Ostwald, at Leipzig, he returned to America to found the new subject of physical chemistry, although for a number of years he continued to teach organic chemistry at the Massachusetts Institute of Technology.

It is not possible to enumerate here the many important contributions that A. A. Noyes made to physical chemistry. It is illuminating, however, to point out that one of his earliest contributions was the enunciation of what has come to be known as the "Solubility Product Principle." Prior to that time, it was supposed that in a solution of an electrolyte the concentration of undissociated molecules remained fixed so long as the compound remained present as solid phase. Noyes recognized that, if this were true, it must also be true that the product of the concentrations of the ions under the same conditions must remain constant The solubility product principle proved much more useful than the principle of the constancy of concentration of the unionized molecules and we now know that the solubility product principle is, in fact, true, while the alternative principle seems to have no foundation in fact, since the concept of a neutral molecule has no meaning in the case of solutions of electrolytes or, indeed, in the case of solid electrolytes.

The application of the solubility product principle to the problems of analytical chemistry led to most important results, and Noyes was among the foremost in applying these principles to analytical problems. Indeed, throughout his life, Noyes actively cultivated the field of analytical chemistry and his monographs written with Sherrill and with Bray are authoritative at the present time.

During the latter years of the nineteenth century and the early years of the present century, the problem of electrolytes was one of the foremost engaging the attention of physical chemists In spite of the success of the ionic theory in many directions, its failure in the case of strong electrolytes was recognized at an early date. Noyes was foremost among the many investigators who bent their energies to the elucidation of this important problem. While the ultimate solution was not reached by Noyes or any other physical chemist, nevertheless, the exact data which Noyes and his co-workers collected on equilibria, solubilities, conductances, freezing points and transference numbers of electrolytes paved the way for the final solution, which was provided only a dozen years ago by Debye and Hückel and Onsager. In the experimental field, Noyes went beyond the workers of his day. He was particularly active in investigating the properties of aqueous solutions of electrolytes at high temperatures, and the work turned out under his direction in the Research Laboratory of Physical Chemistry at the Massachusetts Institute of Technology remains practically the only available source of information in this important field.

Greatly as Noyes was devoted to research, he was equally outstanding as a teacher. His lectures, whenever and wherever given, were models. It was due to Noyes more than to any other one man that the method of teaching physical chemistry in America was revolutionized. He constantly emphasized the importance of general physical principles and illustrated their use and application by the problem method. To-day, practically all texts of physical chemistry follow the method introduced by A. A. Noyes.

If Noyes was outstanding as an investigator and as a teacher, he exerted a still more profound influence upon American science as a research director. Noyes early recognized the need of training prospective chemists in the way of research, and he recognized, in addition, that such training could be afforded only in a properly equipped laboratory. Through his own exertions, he founded, at the Massachusetts Institute of Technology, in 1903, the Research Laboratory of Physical Chemistry which has served as a model of research laboratories throughout the United States, if not throughout the world. Here, for the first time in America, an opportunity was afforded young investigators to carry out their researches in a well-equipped laboratory and under conditions that were ideal. In no other laboratory in the country was it possible at that time for young men to engage in their own researches without the need of eking out a living by undergraduate instruction or by other means. Noyes introduced the idea of post-doctoral fellowships They were not known as such then but were called research associateships. At the research laboratory, Noyes also introduced research assistantships for young men who had not already attained the doctorate.

The research laboratory was not a place where young men came to get direction, but rather a place where they came to carry on research. They came not merely to work under the immediate guidance of any one individual, but, when they were adequately equipped and had adequate research programs, they were afforded an opportunity to carry on their own researches in an independent fashion. The success of the research laboratory under the direction of A. A. Noyes is attested by the large number of eminent chemists who once were associated with that laboratory; such as G. N. Lewis, W. C. Bray, R. C. Tolman, W. D. Harkins, F. G. Keyes, E. W. Washburn, John Johnston, to mention only a few. The old roster of the research laboratory now reads almost like a membership list of the National Academy of Sciences.

Arthur Amos Noyes was an ideal director. While he kept in touch with the work of men engaged on his own problems, he, nevertheless, gave them complete independence in carrying out such work. In the case of others, who were working on their own problems, Noyes always exhibited helpful interest, but never interfered with the individual investigator, every worker in the laboratory not only had an opportunity to solve his own problems, but it was expected of him to do so. It was this impersonal point of view with regard to the problems in the research laboratory that contributed perhaps more than any other factor to the success of the laboratory. Yet Noyes was always interested in the men themselves and was ready to help them on every occasion.

After 1915, Noyes became associated with the Throop Polytechnic Institute, which, through his efforts in conjunction with those of George E. Hale, was ultimately converted into the present California Institute of Technology. Here again, Noyes showed his outstanding ability as a scientific organizer. No one who has watched the development of the California Institute of Technology or of the Gates Chemical Laboratory of that institution can fail to see the influence of Noyes's keen insight. Noyes leaves behind him at the Massachusetts Institute of Technology and at the California Institute of Technology two living monuments to his imperishable fame as founder of American physical chemistry.

Although Noyes spent much of his energy in organizing the research laboratory at the Massachusetts Institute of Technology, he, nevertheless, was always active in research. While many of these researches were carried out with the aid of collaborators, Noyes himself constantly supplied ideas and invariably was the most severe critic in the analysis of the final results. His devotion to research is well illustrated by the fact that during the last two years of his life, when suffering from the aftermath of several painful operations, he continued his work on "Argentic Salts in Acid Solution," the results of which investigation were published in three papers appearing in the 1935 issues of the *Journal of the American Chemical Society.*

Active to the last, A. A. Noyes leaves behind him a heritage of rich accomplishment; his works live after him to do him honor and to benefit mankind.

CHARLES A. KRAUS

THE AWARD OF THE FRANKLIN MEDALS TO DR. KETTERING AND DR. JEWETT

THE Franklin Medals were presented at the annual Medal Day exercises of the Franklin Institute in Philadelphia on the afternoon of Wednesday, May 20. This year the recipients were two Americans who have greatly influenced the lives of their fellowmen by their genius for invention: Dr. Charles Franklin Kettering, of the General Motors Company, and Dr. Frank Baldwin Jewett, of the Bell Telephone Laboratories.

The award to Dr. Kettering was based upon "his significant and timely contributions to the science of automotive engineering—a science out of which has grown the greatest industry in this country, the manufactured product of which has, in only a quarter of a century, changed the face of the civilized world."

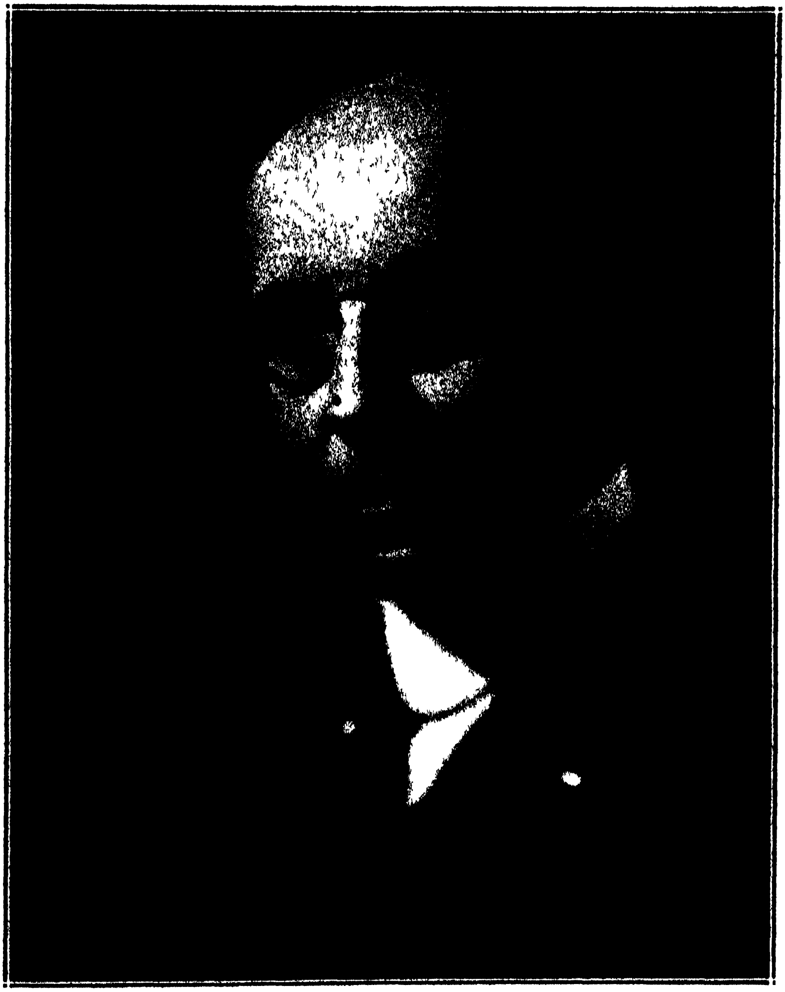
Among the inventions listed as the reason for the award may be mentioned his first, a small electric motor powerful enough to rotate automatically the mechanism of a cash register. His next important contribution, which changed and increased the usefulness of the automobile, was his idea of an electric self-starter for automobiles. The automobile

DR. CHARLES FRANKLIN KETTERING

companies of that period (1911–1912) were not at all enthusiastic about his proposals, but an accident to the close friend of the president of one of these companies, caused by cranking a car, gave Kettering the opportunity to demonstrate how cranking could be eliminated. In 1912 his invention was awarded the Dewar Trophy by the Royal Automobile Club of London for the greatest advance by any motor car maker during the year.

Other outstanding inventions and developments include "Delco-Light," an electric power plant especially designed for farm and rural residences; Frigidaire, of which company Mr. Kettering is vice-president; and several others developed under the name of the General Motors Research Corporation, of which Mr. Kettering is vice-president and director. In the report upon which the award is based, his research which resulted in "Ethyl gas" is also mentioned.

The presentation of a Franklin Medal to Dr. Frank Baldwin Jewett was given "in recognition of his many important contributions to the art of telephony, which have made conversation possible not only from coast to coast, but from



DR FRANK B JEWETT

this country to the other side of the world—contributions of which some were made by him alone and some by him in collaboration with other workers in the great laboratory of research which he organized and which he has directed with such signal success.''

Dr. Jewett began his work with the American Telegraph and Telephone Company in 1904 At this time the telephone field was on the threshold of a great expansion and the value of scientific research was just beginning to be appreciated. Dr. Jewett was called upon to organize a research laboratory to aid in the solution of the many problems involved in the extension of long distance lines from coast to coast in the United States, and in 1915 this was accomplished. This phenomenal extension of commercial telephone service was accomplished by the introduction of phantom loading and the loading of large-gauge and open wire circuits, among other things. By the end of 1915 it was possible to transmit speech across the Atlantic Ocean. It was twelve years, however, before commercial telephone service was opened between England and the United States. These achievements were the direct outcome of the scientific work carried on in the laboratory under Dr. Jewett.

The Franklin Medal, the highest award for physics in the United States, was founded in 1914 by Samuel Insull, of Chicago. It is ordinarily awarded to one outstanding American and a scientist from some foreign country. This year, however, the committee recommended the awards to the two Americans mentioned above.

Medal Day was instituted by the late Dr. Howard McClenahan in 1926, and has become one of the important events in the recognition of accomplishments in the field of science. It brings together in Philadelphia internationally known scientists and diplomats and thus pays tribute to the workers in the laboratories as well as the engineers of great administrative ability.

The Franklin Medal is awarded "to those workers in physical science or technology, without regard to country, whose efforts, in the opinion of the Institute, acting through its Committee on Science and the Arts, have done most to advance a knowledge of physical science or its application."

E. D. C.

THE SIGMA XI SEMI-CENTENNIAL

COMMEMORATING the founding at Cornell University fifty years ago of the Society of the Sigma Xi, nearly seven hundred scientists, research workers and guests from all over the country came to Ithaca on June 19 and 20. Included among them were Dr. Frank Van Vleck, of Washington, D. C, William A Mosscrop, of Hempstead, N. Y., and John Knickerbacker, of Troy, N. Y., three of the men who, while at Cornell University, founded the organization The only living founder not present was Professor Emeritus Charles B. Wing, of the class of '86, of Stanford University, whose greetings were brought by Dr. William F. Durand, president of the national society.

The American Association for the Advancement of Science had adjourned its meeting in Rochester earlier in the week to Ithaca. From the first address by its president, Professor Edwin G. Conklin, of Princeton University, following President Farrand's welcome, the tenor of the meetings was the importance of scientific research to social progress. Again and again, eminent speakers pointed out that, great as has been the progress of science in the past, the very foundations of civilization depend upon the continuance of research, unhampered and adequately supported.

Dr. Conklin emphatically denied that science is in any way responsible for unemployment and other difficulties of to-day, but showed rather that the ills of modern society are the result of the "frustration of science" by the modern social order. He listed some of the

THE SIGMA XI MEMORIAL TABLET

DR. HENRY S. WILLIAMS
FIRST PRESIDENT OF THE FIRST CHAPTER OF SIGMA XI

startling contrasts between the status of knowledge and present conditions, to show graphically the "conflict between progress and stagnation, knowledge and conduct, science and the social order"

Dr. Durand, responding to the addresses of welcome, recalled that in the last twenty-five years Sigma Xi has grown from a constituency of 7,500, largely within the United States, to 35,000, engaged in scientific research in fifty-five countries.

Dr. Van Vleck, recalling the inception of the society, gave credit to two classicists, whose names had not before been mentioned, for an important part in the founding of Sigma Xi. Van Vleck and Wing, technologists, were often consoled, he said, by their two room-mates, George L Burr and Charles H. Thurber, because, "soaked in science" as they were, the two engineers could not be elected to Phi Beta Kappa. In reply, both Wing and Van Vleck predicted that a new society for scientific men would arise. Such a one was definitely suggested to him, he said, by Day as the two toiled up the hill from town in the spring of 1886. Dr. Van Vleck also revealed, for the first time, that it was Burr who first suggested using Greek letters for the name of the new society and who evolved its Greek motto, later approved by Professor Henry Shaler Williams, first president of

THREE FOUNDERS OF SIGMA XI WITH THE PRESENT PRESIDENT
LEFT TO RIGHT. WILLIAM A. MOSSCROP, JOHN KNICKERBACKER, DR. FRANK VAN VLECK AND DR. WILLIAM F. DURAND

the society. Van Vleck and the other two founders present were honored at a reception in Willard Straight Hall on Friday afternoon.

In the great Memorial Room adjoining, throughout the two days, was set up a research exposition of twenty-five striking demonstrations of some of the research being carried on at Cornell University by the younger members of Sigma Xi. Just inside the door were displayed in glass cases some of the original records and other items of historical interest of the society.

Dr. Karl T. Compton, president of the Massachusetts Institute of Technology, speaking on "The Service of Sigma Xi in the Universities of the Future," pointed out that "the geographic pioneer is now supplanted by the scientific pioneer, whose thrill of discovery or urge for reward is no less keen and whose fields of exploration are probably unlimited. Without the scientific pioneer, our civilization would stand still and our spirit would stagnate; with him, mankind will continue to work toward his higher destiny " From his experience of two and a half years as chairman of the Science Advisory Board, set up by the President and disbanded last December, the speaker described the scientific work carried on by the government and reiterated a recommendation made by the board to the President and not yet acted upon, for the establishment of a permanent scientific advisory council for the coordination and general supervision of the government's scientific work in non-military departments. Speaking of science in industry, he showed that those industries which have liberally supported research have been financially more prosperous than those which have not and advocated that technically trained men be given an increasing share in the industry's management. Educational institutions, Dr. Compton said, offer the greatest opportunity for the search for truth:

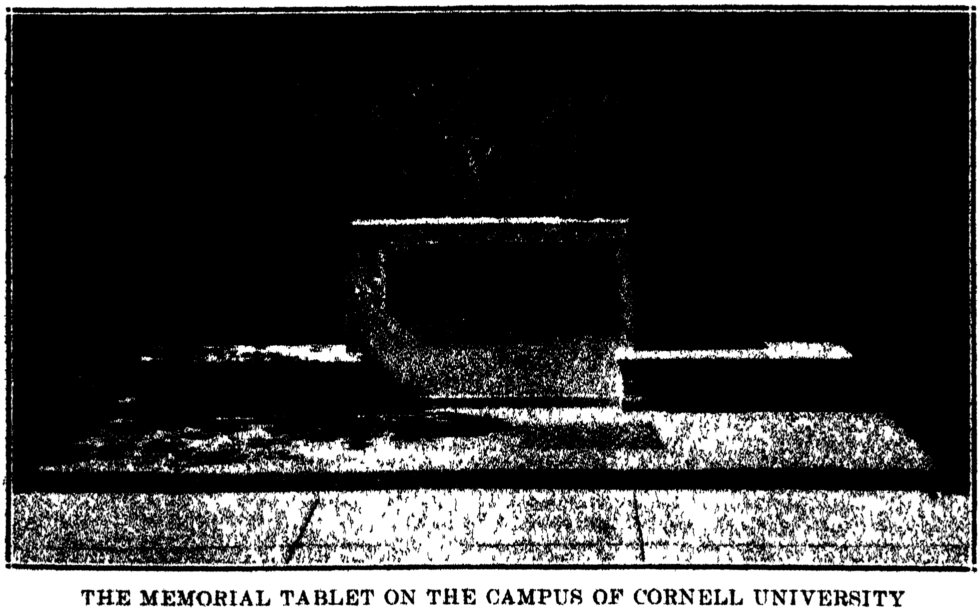
> Scientific discoveries are the seeds of industry and public welfare, and the universities are the nurseries in which they are produced and nurtured to the point where some of them can be transplanted into the fields of industry. I once likened new industries to babies: they need shelter and nourishment, which they take in the form of patent protection and financing. But, before all, they need to be born, and their parents are science and invention. Neither laws nor committees, nor juggling acts, nor wishful thinking can perform the first necessary step of conception. To maintain and advance our civilization we need more and better scientific seeds, and industrial babies. The educational institutions of higher learning are the birthplaces of this new knowledge, as well as the training and proving grounds for the young men and women who will carry this knowledge on and put it to practical use.

The speaker urged that opportunity for science depends greatly upon "overcoming the instinctive prejudice of the scientist against having his work publicized."

Dr. Max Mason, president of the Rockefeller Foundation, speaking on "Science and the Rational Animal," traced the spirit of learning through the three centuries since it came into being. "Man's real problem is himself," he said, citing the disturbances in physical and mental health which have come with civilization and how they are met with knowledge. Advocating the objective approach to the art of living, devoid of personal prejudice, Dr. Mason invited membership in a new organization, Alpha Omega, dedicated to the scientific way of living; its password, "How do you know it?" followed by the question, "What of it?"

"The Alpha Omegas are not universally popular," he said, "for they take an aggressive attitude toward some of the foibles of their friends. They do this because they believe that little things add together to make large things, and that mental attitudes are contagious. . . . They do not keep their passwords secret; they use them every day. . .

"We can not be true to the spirit of science in our laboratories and false to



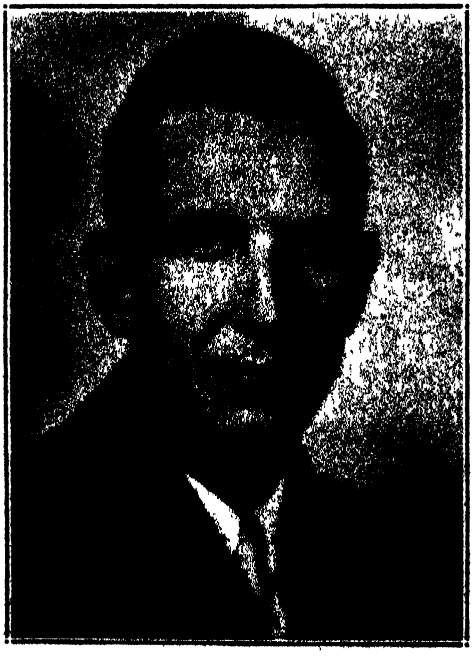
THE MEMORIAL TABLET ON THE CAMPUS OF CORNELL UNIVERSITY it in our lives. We can not have faith in the rationalization of life without seeking to promote it. In that effort we must not overlook the obvious because it is so simple.''

A symposium on Saturday morning on the accomplishments and future of science, with Dr. Willis R. Whitney, vice-president of the General Electric Company, in charge of research, speaking for the physical sciences, and Professor Frank R. Lillie, of the University of Chicago, speaking for the biological sciences, brought agreement that by its very nature, the future of scientific discovery is essentially unpredictable. They agreed, however, that ''without research there is no increase in knowledge and no progress in ideas,'' and that the lesson for society is to support free and independent research and to have abiding faith in the future results ''

Dr. Whitney said:

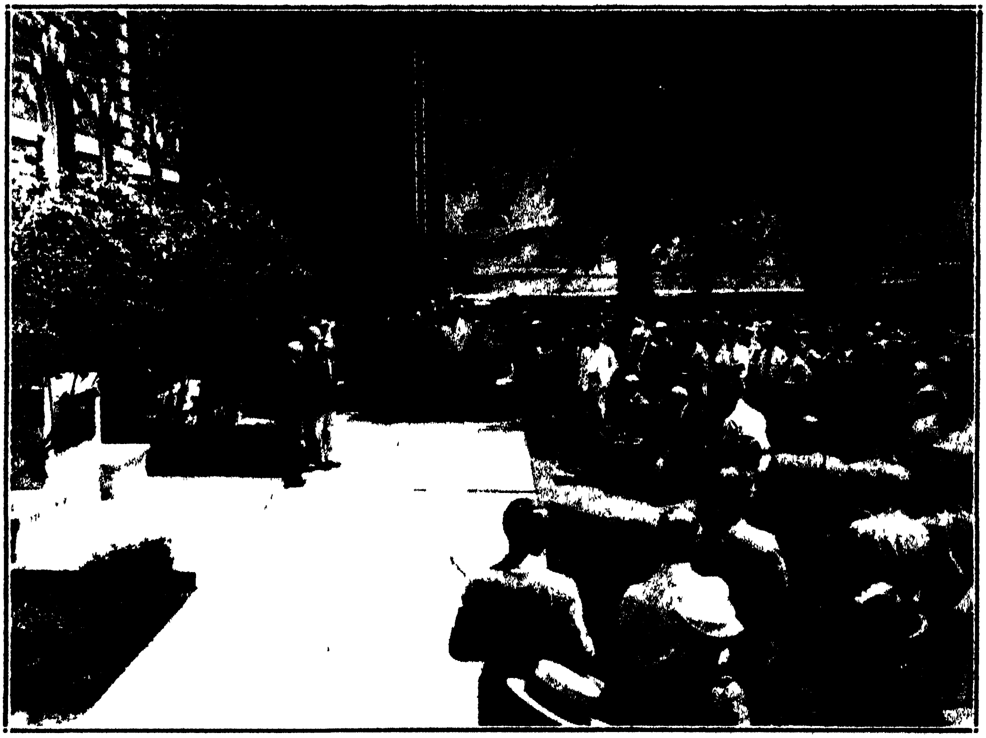
> There are no little or big discoveries to be made, but only true ones. . . . If industrial research were done by more and better people, we should have less unemployment, and perhaps none. . . . Research is the result of childlike inquisitiveness, and we are likely to check that inquisitiveness, as we do a child's, because we are lazy. . We almost need to provide more ''accidents,'' for it is frequently the unexpected effect which drives a researcher into a new and productive field. . . . Scientific research is fishing with a tiny scoop-net in oceans of unfathomable depth and infinite area. We make the nets ourselves. Our catches often make a disordered pile, but we may orient them and fit them together as we do jigsaw puzzles. Then some one may give our puzzle one more dimension, like depth, and then we have a new necessity. . . . I doubt if it is recognized that the average research worker is a healthy, justified kind of unselfish communist. He aims at everything and works for everybody He pays personally for the spread of his propaganda, and broadcasts freely all his home grown produce. . . . The expense to a good worker may exceed several hundred dollars a year. The better he does it, the more it costs him. . . . When all is said and done, there is only one thing worth advancing, and that is the mentality of the man.

Sigma Xi semi-centennial research prizes of $1,000 each were presented, for work in the biological sciences to Dr. Richard E. Shope, of the Rockefeller Institute for Medical Research at Princeton, N. J., and for work in the physical



DR. RICHARD E. SHOPE

PROFESSOR ISIDOR I. RABI



THE PRESENTATION OF THE MEMORIAL TO PROVOST MANN OF CORNELL UNIVERSITY

sciences to Professor Isidor I. Rabi, of Columbia University. Eighty-five candidates were nominated by the chapters and clubs of Sigma Xi. In making the awards, Dr. Durand explained that the field of choice comprised "those already engaged in research and with notable work accomplished, but who might not be considered as yet having arrived at the full measure of their stature in science"; and that the awards were made "as a stimulus to research in progress and in the future, rather than as a reward for past and completed accomplishments." Dr. Shope's award is for work done on the etiology of swine influenza, particularly for determining the dual nature of the disease and thus establishing a principle which it is believed will have wide application in the control of infectious diseases. Dr. Rabi was recognized for his work on molecular beams and especially on the magnetic moments of the proton and deuteron, and because of the promise that this work holds for the future.

On Saturday morning, in the presence of three of the founders, Dr. Durand unveiled and presented to the university a memorial tablet, bearing the inscription:

The Society of the Sigma Xi
Devoted to Research in Science
Has Placed This Tablet Here
On its Fiftieth Anniversary
To Commemorate the Founding
At Cornell University
1886 1936

The tablet is set in a monument of Indiana limestone, erected by the university, with a stone bench at either side and a stone terrace before it. Set in a bay in the shrubbery near the southwest corner of Sibley College, it overlooks the main quadrangle. The bench was designed by Professor Alexander D. Seymour, architect, and the tablet by Professor Harry P. Camden, architect. Accepting the memorial, Provost Albert R. Mann, who is president of Alpha Chapter of Sigma Xi, expressed the hope that "as one of Cornell's most treasured possessions, it will beckon countless generations of youth to a fellowship rich in its tradition and prophetic in its significance." L. C. B.

METEOROLOGICAL ASPECTS OF THE 1936 DROUGHT

At times of great national disasters caused by nature's vagaries there is a disposition to become panicky, to be convinced that the old order is changing and to believe that we, as a people, must adjust ourselves to a new régime. Many are expressing that thought in connection with the present drought, especially as it is the third that has occurred within so short a period as six years. Is there sound basis for such pessimism? Not if we can take past records as an indication of the future

It is characteristic of precipitation records, in the long run, to vary in wave-like progression. That is, when short-period fluctuations are smoothed, there appear successive up-and-down trends, covering comparatively long periods of time and, in general, the difference in the rainfall for the phases of comparatively heavy and those of light amounts is marked. Such a tendency is shown, for example, in the records for the Great Plains, especially the central and northern portions. Thus, the normal annual precipitation for western Kansas is 19 inches. The 5-year average, 1902–06, was 22 inches and that for 1931–35 was 15 inches. Again, taking a single station, the average for 1891–95 at Dodge City, Kansas, was 16.5 inches, but for the following 4 years it was 25.5 inches, or more than 50 per cent. greater. Numerous other examples might be given They all lead to the definite conclusion that the present succession of dry years is by no means unprecedented and that we may expect a return to normal and even above normal conditions. Unfortunately, we can not say as yet when that return will begin.

Optimism as to the future does not help very much, however, so far as the present situation is concerned. During this year, beginning with January, precipitation has been persistently scanty in most sections of the country. For the six months up to July 1 scarcely half the normal had been received in a considerable northwestern area and also in much of the interior, while nearly all sections between the Rocky and the Appalachian Mountains had less than three fourths normal. May and June, especially June, greatly intensified droughty conditions. For these two months the northern Great Plains had scarcely one third normal and less than half was the rule in the Ohio and middle Mississippi Valleys. It was the driest June of record in several states.

At this writing, July 10, the picture has changed somewhat in the South and East. During the first week in July generally heavy rains quite effectively broke the drought from Texas, Arkansas and southern Missouri northeastward to the Appalachian Mountains. However, from the Ohio River, central Missouri and northern Texas northward and northwestward only a few localities had received more than very light showers. This condition has been very greatly aggravated by abnormally high temperatures. The maxima have ranged well above 100°, even up to 120° in places, day after day since July 2, throughout a large area from the western Ohio and central Mississippi valleys northwestward. Unless rain and lower temperatures occur within the next two weeks, this drought will undoubtedly take its place as the worst in the history of this country and as one of the worst in the history of the world.

Willis Ray Gregg
Chief, U. S. Weather Bureau

EFFECT OF THE 1936 DROUGHT ON CROPS

THE weather of 1936, up to this writing, July 11, has been decidedly unfavorable for agriculture over the greater portion of the United States. Precipitation of the winter and early spring was very scanty in the Southwest, where the soil became extremely dry, and severe dust storms caused much damage by drifting and by blowing out winter wheat. However, in May there was a reaction to abnormally heavy rains, materially improving conditions, they were especially helpful to winter wheat over large areas, particularly in Kansas. These western May rains were largely responsible for the comparatively good showing of the 1936 winter wheat crop in the United States.

While May rainfall improved the outlook materially in the Southwest, other parts of the country were less fortunate, and droughty conditions slowly, but surely, developed. Dry weather in May and June brought wide-spread damage to early truck, hay and pastures, the latter becoming very poor in nearly all sections between the Appalachian and Rocky Mountains.

The spring was the driest of record in many southeastern sections, and great harm resulted to early crops in a considerable area, especially from North Carolina southward to central Alabama. It was too dry for cotton to germinate, and many spotted fields resulted. As before indicated, the winter wheat crop was not seriously affected by this year's drought, principally because of May rains in the western portion of the wheat belt, and comparatively cool weather in the eastern part, though it became decidedly dry and some deterioration resulted, especially in northern districts The Northwest was entirely too dry for spring wheat, though up to the beginning of July temperatures had not been persistently high.

During the first week in July crops benefited materially from rain over much of the South, but rainfall was insufficient in Georgia and some adjacent sections. This month ushered in a period of extremely high temperatures in the mid-West and Northwest, which were disastrous to spring-sown small grains. The heat and drought seared what little pasture was left, and dried up available stock water. With neither feed nor water to be had over large areas, the live-stock situation became desperate, with heavy shipments necessary to prevent deaths by the thousands from starvation and thirst The spring wheat crop and other small grains in the Northwest were severely damaged, but conditions continued favorable in the North Pacific area.

Up to July 1, corn had not been seriously harmed over wide areas, but the extremely high temperatures and lack of rainfall were beginning to be felt materially by the 10th of the month, with considerable irreparable damage in evidence by that date, especially in the southwestern Corn Belt. At this writing, July 11, much of the corn crop is entering a critical stage of growth, and it is certain that, if high temperatures and dryness continue for an appreciable time, there will be a major disaster to this important American product. The fate of the corn crop will be decided largely by the weather of the two weeks succeeding July 11.

J. B. KINCER

CHIEF, DIVISION OF CLIMATE AND CROP WEATHER, U. S. WEATHER BUREAU

ACTION OF FLUORIDES UPON HUMAN TEETH

MOTTLED enamel, or what is now known scientifically as chronic endemic dental fluorosis, is a water-borne disease associated with the use of domestic waters containing toxic amounts of fluorides. The toxic action of the fluorides upon the teeth is apparently operative only during the period of dental calcification; consequently the susceptible period for the human is between birth and eight years of age. The second, or permanent dentition, is particularly affected.

Normally calcified teeth erupt, presenting a smooth, glossy, translucent structure, generally of a pale creamy white color. Teeth affected with mottled enamel, on the contrary, erupt, showing a dull, chalky-white appearance which in many instances later take on a characteristic brown stain, the frequency of brown stain increasing with age. In areas where the water contains a relatively high fluoride concentration the teeth may in addition be marked by discrete or even confluent pitting. As the defect is structural (an endemic dental hypoplasia), the result is a permanent physical disfigurement of thousands of children residing in endemic areas during the period of tooth formation.

At present there are approximately 335 surveyed or reported endemic areas in this country alone distributed among 25 states. Because of the high incidence and its wide-spread distribution, it is a public health problem of country-wide interest and particularly appropriate for study by the national health service. Although the objective sign of endemic fluorosis is dental, this disease may be one of multiple ramifications. It is becoming one of increasing interest to physicians, especially pediatricians, epidemiologists, sanitary engineers, water chemists, biochemists, geologists and veterinarians.

Studies by the United States Public Health Service during the past few years, in addition to largely augmenting the number of known endemic areas, have demonstrated the importance of studying this problem from a quantitative point of view. In this connection there has been developed a quantitative classification for clinical diagnosis and a standard method for determining a community mottled enamel index. It has also been shown that there is a definite quantitative relation between the fluoride content of the communal water supply, the incidence of affection and the percentage distribution of severity, particularly the latter. Earlier studies at the National Institute of Health, in addition to confirming the findings of earlier workers regarding the fluorine hypothesis, indicated that a given concentration of sodium fluoride in the drinking water produced a more toxic reaction than the same concentration of sodium fluoride in the diet. Carefully controlled epidemiological studies are being carried on at present for the purpose of obtaining definite information concerning the maximum amount of fluoride permissible in a domestic water supply. Studies to date indicate that amounts not exceeding one part per million are of no public health significance.

In the light of present knowledge this disease is readily preventable if water free of toxic amounts of fluorides is used during the susceptible period for both drinking and cooking. Several small communities have actually changed their public water supply to one free of toxic amounts of fluorides in order to prevent the further development of this defect. In many endemic areas, however, this mode of action is not feasible and final solution will no doubt be dependent upon the development of an economical chemical method of treating the present supply.

H. Trendley Dean

Dental Surgeon
U. S. Public Health Service

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THE SOCIAL ORIGINS OF DIETARY HABITS

By Dr. ROE E. REMINGTON

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In 1906 Dr. Henry H. Donaldson, of the Wistar Institute, published charts and tables showing normal growth in the albino rat, an animal which has been bred in captivity for many years and extensively used for research purposes. His rats were reared on what was supposed at that time to be a fully adequate and satisfactory diet. During the thirty years that have followed, as our knowledge of nutrition has grown by leaps and bounds, and has been reflected in the improved feeding of rat colonies in our research laboratories and scientific institutions, the rate of growth of normal rats has been trebled, and adult size increased, so that it is now common to find mature male rats weighing as much as 700 grams, a thing that was unheard of thirty years ago.

The pangs of hunger drive man to seek food. This has always been true, but it remained for Carlson to show that hunger is a concomitant of more or less powerful and spastic contractions of the stomach. To allay hunger, one eats, and derives pleasure in the eating, but the choice of articles which he uses as food depends on availability and appetite. It is appetite which leads us, when given a choice, even though limited, to eat one article and reject another.

The modern biochemist, with his vast accumulation of data as to the human requirement for protein, fat, carbohydrate, mineral and vitamin, and with tables of analyses of all common foods to guide him, finds that many peoples in many places, when guided by appetite, that is to say, by customary usage, do not select for themselves a fully balanced and adequate ration.

This newer knowledge of nutrition, for which we are indebted to the sciences of chemistry and physiology, has found rapid and ready acceptance among breeders of live stock, who have a financial interest in the result, but its influence on human dietary habits has been much less evident, so that it has seemed of interest to inquire as to the origins of the food habits of man, different races of man, in the light of the degree to which they may have been influenced by a conscious or subconscious knowledge of biology and chemistry, by geography, by economics, by religion or superstition or by the general mode of life and pursuits of different peoples. These latter factors, derived from the geographical, economic or social status of the people, I shall consider under the name of social factors, as contra-distinguished from the chemical composition and physiological value of the food itself, which I shall call biological factors.

A study and evaluation of the social factors which have influenced the diet of man is vastly more difficult, and less certain, than of those in which chemistry and physiology are involved. It leads us back to the very dawn of human life, concerning which we must indulge in a certain amount of speculation of a kind which is more or less repugnant to the modern scientist. It leads us to consider the religions of man throughout the ages and his tribal customs in so far as they prohibit or encourage the use of this or that article of food. It leads us to consider the nature of the land in which he dwelt, whether adapted to an agricultural, a pastoral or a nomadic life and, finally, it leads us to study commerce and industry.

Even to-day, and among the most enlightened people, we find widely current the belief that our pioneer ancestors or even their semi-savage progenitors, eating the products of field and forest, grinding their grain in a crude mortar and without access to modern refined foods, enjoyed a more complete and rational nutrition than do we to-day. Civilization, they say, has led man to discard and forget the rules of a sane and rational dietary régime and has created perverted tastes and appetites which are undermining the vigor of the race. To hold with such a view we should have to postulate that primitive man possessed an instinct which led him to accept this or reject that, from among all the plants of the fields and the game of the woodlands, according to his own physiological needs. Many still believe that, despite his veneer of civilization, man to-day possesses this instinct, which expresses itself in his likes and dislikes and which has been inherited from his jungle ancestors. Such an instinct can not be demonstrated with certainty among the lower animals, which are still wild and have free choice. From my youthful days on the farm, I recall that a horse must be taught to eat oats, a calf to eat clover, and that any abrupt change in ration will cause animals to "go off their feed," even though the new ration be as complete and perfectly balanced as the old. The dog, a domesticated wolf, will not as a rule eat fish, perhaps because in his free state fish was inaccessible to him. I know a Belgian police dog that suffered at one time from black-tongue and for which canned salmon was prescribed as an anti-pellagric food. He could be induced to eat it only by starvation and never learned to take it willingly. On the other hand, I have a terrier which was raised with a family of kittens, which were taught by the mother cat to eat fish. The dog ate the fish to get it away from the cats and thus acquired a fondness for it while still young. If such an instinct exists, it is an instinct, common to man and animals, of distrust for anything the taste of which is strange or new.

Bordeaux, in his history of alimentation, published in 1884, says of primitive man that "oppressed by constant hunger he ate, according to chance, his only provider, without being able to choose; unsuitable prey and repulsive food, insipid or sour berries, suspicious fruits and larvae of insects, mollusks, batrachians, reptiles, and even at need the grass of the prairie. There were more things capable of being eaten and of furnishing some nourishment, good or bad, than we suspect to-day. Originally necessity caused all of them to be eaten." Engels says: "Primitive man, escaping from the animal kingdom, still retained traces of his ancestry. He was a semi-beast, crude, weak against the forces of nature, ignorant of his own strength, and for that reason just as helpless as the animals." Roubakine, from whom I have drawn freely in the argument which follows, says of man of that age that "in the forests of the quaternary period he gathered roots, tubers, grain, and some wild fruits; caught larvae, worms, grasshoppers; ravaged the nests of birds and ate their eggs. Not having equipment or strength to catch or kill large animals, he ate such small ones as he could waylay, or the flesh of dead animals which he might happen to come upon. In the sea and rivers he obtained crustaceans and shell-fish."

The eating of insects did not perish with prehistoric man. The Hebrews were permitted to eat grasshoppers and locusts, and in fact employed quite a variety of insects. John the Baptist was nourished, during his stay in the wilderness, by locusts and wild honey, and it is said that the Greeks applied the epithet of "acridophages" to the people of Lybia because they ate grasshoppers. Even to-day they are served in China under the name of "shrimps of the earth." The Romans ate, as a delicacy, the larvae of several species of beetles, and the East Indians and Africans use ants as a delicacy.

So far as primitive man is concerned, his struggle for existence was so difficult that he could not exercise much choice as to his food. He had to eat what he could get or die. Eating was synonymous with life, a fact which finds expression in the idioms or origins of words in most languages In English we speak of "one's living," as applied to food; in French "être," in German "essen," in Latin "esse," in Russian "ieste," all have the same double meaning.

Naturally there were some among the articles used as food by primitive man which caused illness or even death. With his rudimentary reasoning powers, it must have taken many years for him to learn to avoid them. Can it be that such knowledge, handed on from generation to generation, could have fixed itself in human physiology in the sense of taste? But, if so, why should taste, acquired as a protection against harmful or poisonous foods, lead one race of mankind to rely heavily on a certain article of food, another to reject it *in toto?* Take, for example, so common and, among us, so universally used an article as milk. Savage man had no domestic animals, hence did not have milk, which only appeared as an article of diet with the coming of pastoral peoples. Even so, not all keepers of live stock used milk. Homer referred to milk as food suitable for barbarians, whom he called "galactophages," and Herodotus thought it worthy of note that the Scyths employed milk as a usual food. Bordeaux says that in China and Eastern Siberia milk is not used at all, the people of these regions calling it "white blood" and having a distaste for it. In other words, the use of the milk of animals as human food did not arise through an instinctive sense of taste, but rather because the domestication of lactating animals made it available, and perhaps only then because scarcity of other food made it necessary to rob the calf to feed the baby.

In the recorded history of some uncivilized peoples, and among certain savage tribes to-day, we find that different rules of diet are laid down for different classes; some articles of food are forbidden to women and children but permitted to men, or other articles are restricted to a special group. Let us speculate for a moment as to how this may have come about. Before the invention of weapons or the advent of tribal life, the obtaining of food could be as easily accomplished by the female as the male. Monogamy and the family did not exist, and there was complete equality between man and woman, a condition which has not obtained since, even to our day. Except that babes and children were cared for by their mothers, there was no division of labor. The aged and infirm were abandoned to perish.

Perhaps through accident, man learned that he could bind the tusk or horn of an animal to a staff, and thus become superior to the beasts, in that he could kill them at a distance. As implements of the chase became improved and perfected, there arose a division of labor, first between men and women, later between men of different ages. The weapons of the chase were heavy, and required a certain degree of strength and skill in their manipulation. The hunters thus became the select class, for whom the best in the way of food and other necessities of life should always be reserved. But the old men, wise in the ways of game and experienced in making weapons, acquired a new value to the tribe, and hence were no longer left to die, but provided for as equal or only slightly inferior to the hunters.

Since the fortunes of the chase were variable and not to be depended on at all seasons, the products of the field could not be entirely abandoned, and it was the women who devoted themselves to the harvest. They gathered seeds, herbs and fruits, learned to plant and till the soil, and so agriculture was born. Among most primitive peoples the god of the flocks and forests is a male and that of the fields a female.

This division of labor between the hunt and agriculture has been responsible for differences in social usages and tribal customs. Where there was an abundance of game and little reliance need be placed on tilling the soil, the dominance of the male was unquestioned. But where the hunt was precarious, and the main subsistence of the tribe derived from the fields, woman ruled the tribe.

This division of labor resulted in some social usages among primitive men which still exist among certain savage peoples. Among these are: men were forbidden to eat the flesh of female animals and women of male; if such a prohibition existed among enlightened peoples we should doubtless explain it by referring to the hormonal secretions of the gonads! Woman was forbidden to hunt lest she frighten the game (hunters still think so); the best parts of the game and of other food were set aside for the old men; women and children were forbidden to eat certain parts of the game. Spencer cites the observation of Edward John Ayre that numerous such rules of diet exist among some wild tribes in Australia, prompted not by a knowledge of physiology or chemistry, but by the desire of the grown men to reserve for themselves the best parts of meat and fish. In these tribes the young are not allowed to eat of the meat of the emu, of pork or of large lizards, for if they do their bodies will surely swell up and their hair turn white. A woman must not eat of the wild guinea, for if she does her cheeks will swell. Eating of the wild dog will bring on a goiter, or of the kangaroo will cause her head to swell, or the wild hare her entire body to swell. If she eat fish she will surely have ulcers on her legs. But strangely enough none of these things happen to men who consume such delicacies. The rules of magic and primitive religion are called into play to insure observation of these taboos, designed to protect the males in their right to the choicest and best of the food.

The domestication of animals must have originated early in tribal life. Occasionally, in the chase, animals could be taken alive, and were preserved, perhaps against a day of want, more likely for fattening. It was inevitable that man should learn that the flesh of such animals, confined and well fed, was tenderer, fatter and altogether more appetizing than that of wild game. Land had little or no value to primitive man—there was too much of it. The first wealthy were those who possessed large flocks. Naturally meat became an important article of diet among pastoral peoples. It was so in the early days of our own era on the western plains of North America, where stock-raising was the principal industry. But the cattle man ate beef, the sheep man mutton, as the meat most available to him, not because beef was a better food for the one or mutton for the other.

We shall not speculate as to how or when man acquired his taste for cooked food. The use of fire antedates recorded history. The discovery that by cooking the tough flesh of wild game could be made easier to chew, and perhaps to digest, must have been a great boon to mankind. But fire is not the only means utilized to soften food. Roubakine relates that the Kalmouks and the Kirghizes, who live in the steppes of western Europe, where the only fuel is dry grass and the dung of camels, place strips of meat on the backs of their horses, between the skin and the saddle. After a day's ride the meat is considerably softened. This custom did not arise from a perverted or depraved appetite, but from a lack of fuel. The practice of allowing meat to hang for some days to ripen, that is, to be softened by the digestive enzymes of its own juices, is well known.

But the introduction of cooked food must have created somewhat of a social problem. We can imagine that tremendous resistance must have opposed it at first. It could be argued, and doubtless was, that such soft pabulum would result in a tribe of mollycoddles, with inferior physique and stamina. There may have been taboos against it, and food riots, as there were in Europe in comparatively modern times, following the introduction of the potato and attempts to compel its use. More interesting to us, however, is its effect on the dietary habits, that is, the instincts of man as related to the choice of food. Certainly it could not have come about abruptly. All cooked foods taste altogether different from the same foods in the raw state. An entirely new set of criteria (instincts) must become firmly established, so firmly indeed that civilized man would not consider eating raw flesh under any circumstances and eats raw vegetables with considerable reluctance. This change from raw to cooked food is another argument for our theory that dietary instinct is a distrust for the unknown, for those things of unfamiliar taste, and nothing more.

We now come to consider what effect religion (or superstition) may have had in the formation of dietary habits. All primitive religions are religions of sacrifice. Man feared his gods and placated their wrath or won their approval by the sacrifices which he placed on the altar. Naturally, no god could command the respect of his subjects if he could be appeased by inferior offerings. It is the choice of the flock, and the best parts of the slaughtered animal, that are to be placed on the altar. This admonition is clearly set forth in the first chapter of the book of Leviticus. The priests who tended the altars took for their own sustenance from among the sacrifices placed there by the faithful. Thus the priests had a double motive in enforcing the laws of their religion as to sacrifice. First, the authority and superiority of the gods could only be maintained by the insistence that they could accept only the choicest and best. Second, the priests, for their own selfish interests, would insist on the same thing. The authority of the priests to take for themselves of the food placed on the altar is set forth also in the book of Leviticus.

The parts demanded, in most such cases, were the entrails and the blood. This leads us to the conviction that internal organs and blood may have been once highly esteemed as articles of diet. But, their use being proscribed, man came, throughout the generations which followed, to look upon them as not fit for food. To show that this position is not sound physiologically, we have only to cite the experience of keepers of zoological museums. Lions and tigers fed only on muscle flesh sicken and die, but if the internal organs of the slaughtered animals are added to the menu, they thrive. The feral beast which, beset by pangs of hunger, brings down a deer, tears open the carcass and disembowels it, disdaining to touch the muscular tissue until all else has been consumed.

The rite of burnt offering disappeared with advancing civilization, but the distaste for liver, kidney, stomach and other glandular tissue persisted. The ban of religion, being lessened or removed, however, man had no scruples against eating them if need required. The pioneer settler in America made sausage of the liver and blood and other, to him, less desirable parts of the butchered animal. He pickled the stomach into tripe, and cleaned the intestines for sausage casings Sustenance was scanty and hard to come by. He dare not discard any part of the carcass that could be put to use. Nevertheless, the distaste for glandular organs is extremely prevalent. Relatively few people to-day eat liver, sweetbreads or kidney stew. And to complete this remarkable picture of the cyclical course of a distorted dietary habit or instinct, we need the findings of modern medical science that the liver is a wonderful storehouse of minerals and vitamins not found in flesh and that the mucosa of the stomach supplies a factor widely used in the treatment of pernicious anemia.

Religions of primitive man were also called into play to reinforce the taboos previously mentioned as arising from division of labor between sexes or between people of different ages. Certain forms of food were forbidden by religion for reasons, possibly economic, possibly of other origin. A whole series of animals was forbidden as food to the Jews. We can readily understand why such a proscription should run against the camel, an important beast of burden. The animals permitted to be eaten were those with parted hoof, and which chewed the cud. This practically limited them to cattle, sheep and goats, and, being a pastoral people, it is quite reasonable to believe that the live-stock industry would strive to utilize religion to stamp out the competition of cheaper forms of meat, the hog and the rabbit, just as, when the cattle barons ruled the great plains of North America, the introduction of sheep was contested with every legal and illegal method, including arson and bloodshed. The ranch owner refused to eat mutton or permit it to be served to his family or guests, not because he considered it less wholesome and nutritious than beef, but because to him the entry of sheep-raising into the country meant economic loss or even ruin.

With our knowledge of to-day, we could justly ascribe the proscription of pork to a desire to protect the people from the dangers of trichina, that of the rabbit against those of tularemia, but by no stretch of imagination can we impute a knowledge of these parasites four thousand years ago nor a reasoning power that would connect an illness with the eating of infected meat days or even weeks before.

Both the Jews and the Mohammedans were also forbidden to eat the meat of animals which died other than by slaughter, but strangely enough, the Jews were charged to give it to travelers or sell it to foreigners, whose nutritional needs were doubtless different from their own.

Let us next consider the distribution of man on the face of the earth, and what effect it may have had on his dietary habits. It is simple to trace the effects of temperature, but some other geographical influences may be more obscure. The polar Eskimo, residing in regions where vegetation is absent or scanty, subsists almost entirely on meat and fat. Stefansson, who has spent a total of nearly five years in living with the Eskimos, reports that their native diet is composed entirely of raw and boiled fish, the game having been exterminated by the intensive hunting that supplied meat to the whaling fleets of fifty years ago. In spite of this seemingly monotonous diet, he did not observe a single case of rickets, scurvy or carious teeth. That a carnivorous diet can maintain members of the Caucasian race in health and vigor for considerable periods of time has also been demonstrated by Stefansson, who, under the observation of scientists of the Russell Sage Foundation, lived for a year on meat and fat alone. Tropical peoples subsist to a greater extent on vegetables and fruits. Is this because the requirements of life in the tropics do not call for the specific dynamic action of a high-protein diet or because fruits and other products of vegetable origin are easy to obtain in tropical regions, but practically unavailable in arctic areas? Is this difference in dietary habits due to a difference in physiological requirement or a difference in the kind of food most available? We incline to the latter view.

An interesting sidelight has to do with the use of salt. According to Morse, the normal daily human urinary excretion of salt is fifteen grams (half an ounce), and it is said that man is the only animal to have acquired such an appetite for salt as to eat it in excess of his daily needs. Salt was so highly esteemed by the ancients that the wages of Roman soldiers were paid in this commodity, hence the word *salarium* or salary. Nonetheless, the Eskimos, far from using salt, actually have a distaste for it. Stefansson states that in his first winter with them he was so beset by hunger for salt that he boiled down some sea-water, but that when he added the resulting brown powder to the pot of cooking fish, his Eskimo hosts politely declined to partake. He also reports that the deer in Maine do not crave salt, while those of Minnesota do. To me, it appears probable that men and animals subsisting largely on grain and vegetables, which contain an excess of potassium over sodium, as compared with the composition of the tissues and fluids of the body, would require salt to correct this inbalance, while those of purely carnivorous habits would require less or none. It may be that the herbage in Maine and other coastal regions is enriched in salt by the spray from the waves of the sea, blown inland and deposited on the foliage or in the soil. I was interested to observe, on a visit to Itasca State Park in Minnesota some years ago, that the primitive outhouses erected for the convenience of visitors had had their foundations almost entirely eaten away by hedgehogs and other small animals, who gnawed away the wood to get the salt from human urine which impregnated it. The craving for salt doubtless has a sound physiological basis among animals and men subsisting largely on products of plant life, but why does man take so much of it that he excretes half an ounce daily? It is common for physicians to limit the salt intake of patients suffering from arterio-sclerosis or hypertension, but on what grounds is not clearly evident.

The banana, a food of considerable importance in the West Indies, had to await the development of cold storage in transportation before it could be widely used on the continent of North America. Even yet the cost of bananas in the north central states is so high that they can not be used as a staple food. The pineapple, so commonplace in the Hawaiian Islands, had to wait for the development of the canning industry before it could be considered other than as a great luxury in the United States.

Geography has had an important part in developing the dietary habits of man. Wheat, the great bread-stuff of the American people, does not thrive in semi-tropical climates. Corn, on the other hand, is a tropical plant which has made its way north. Corn plays a much more prominent part in the diet of natives of South Carolina and Georgia than does wheat. Still more interesting is the story of rice, which was introduced early into Carolina and the growing of which developed into a great industry. No rice is grown in this region now, nor has been for many years, but it is still one of the most important staple foods, seen daily on the tables of all native South Carolina families. Inventive genius devised a way to scour the bran coat off of rice, rendering it more pleasing to the eye and easier to masticate. For this reason polished rice came to be preferred, but with disastrous results to some Oriental peoples, who subsisted quite largely on rice and fish. A mysterious multiple neuritis (beri beri) took its toll, until about 1908, when two Dutch physiologists, Eijkman and Grijn, demonstrated a vital factor (vitamin B) in the bran that was scoured off and thrown away or fed to pigs. The sense of taste was inadequate to warn man that the new product was inferior to the old; in fact, he liked it better. He ate rice because his parents had eaten rice and because it was available to him at low cost. Grijn demonstrated effectively the fallacy of polishing rice, but none but polished rice is sold in the markets of the world to-day.

One might enlarge still farther upon this matter of geography, but it hardly seems necessary. It is, however, intimately bound up with that of economics, as we shall now see. The easiest and cheapest way for primitive man to obtain meat was the hunt. There was usually plenty of game if he could get it. With the increase of population and improvement of weapons, game became scarce, and it was easier to raise his meat than to hunt for it. With still further increase in population, land became of more value, and when it became possible to sell or barter grain to others, some parts of the soil could produce more returns in wheat or corn than they possibly could in cattle. Naturally, people inhabiting such areas came to depend largely on tilling the soil, and became more vegetarian in their habits than those who dwelt in rough, broken or arid regions, regions which would not yield a profitable crop, but could furnish pasturage to animals. In fact, this increase in population has worked to further increase the value of land in some localities, to a point where it could not possibly be used to produce live stock.

Roubakine reminds us that in Russia, before the revolution, the amount of land available for agriculture had remained the same for an entire century. But population having increased rapidly, the individual parcels had become smaller and smaller, and it became increasingly difficult for the Russian peasant to feed and clothe himself by the products of his own land, and almost impossible to feed live stock. It takes considerably more acreage to feed a goat or a bullock than to feed a man. Nevertheless, although he must have some animals to do his plowing and carry his burdens, he can not afford to raise his calves or his lambs. The Russian peasant is to all practical purposes a vegetarian, eating on the average less than twenty pounds of meat per person per year, and this in the form of veal or lamb. This should not lead us to conclude that such a low meat consumption is physiologically optimal or that the flesh of calves and lambs is more nourishing than that of beeves or sheep. He eats what he can get, not what he would if he had free choice. Even to-day in Germany, the farmer can sell all the grain he produces at a good price, but there is a scarcity of meat because most of the grain that can be raised is needed to feed the people themselves, with very little surplus for live stock.

To the Hindu peasant his goat, who carries his burdens, works his land and feeds his children with her milk, has an economic value far greater than if he were to kill her. In fact, his religion forbids him to do so. For similar reasons the cow is sacred in India. This paucity of land is still more acute in China, where the peasant never gets enough to eat. Meat is almost an unknown luxury to him, and what meat he does get is pork, which can be produced more economically than beef or mutton. The opposite side of the same picture is revealed in pastoral peoples of Turkestan, one of whom finds it easy to slaughter a lamb or sheep from his flock to regale his family or guests, but extremely difficult to provide grain or bread for them.

But food habits are so slow to change that emigrants carry with them into their new habitat their accustomed likes for national dishes, and abandon them only under force of necessity and with great reluctance. Norway and Sweden are rough and mountainous countries, not particularly suited to agriculture, but, on account of their extensive seacoast, well adapted to fisheries. Fish has a prominent place in the dietary of Scandinavian peoples: they have learned various ways of smoking, salting, pickling and otherwise preserving it, as well as ways of preparing it for the table unknown in other lands. Wisconsin and Minnesota are largely settled by Norwegians and Swedes, who, despite the scarcity of fish in this inland area, still maintain their esteem for it, so that tremendous quantities of smoked, dried or salted fish are imported and consumed by them. Indeed, the ordinary country grocery store in Minnesota offers a wide variety of foods unknown and unobtainable in South Carolina.

Let me refer again to the economic value, as contrasted with the nutritive value, of an article of food. To a baker in the city, bread is an article of commerce, which he makes and sells in order to provide for his needs and those of his family. Its value to him as an article of commerce depends on the price it will bring. Its value to him as an article of food depends on its chemical composition and digestibility. The two measures of value are quite different, and yet it seems almost inevitable that they become confused or merged into one idea in the mind of the baker. The fancy breads and cakes which command a higher price appear to him more desirable as articles of food also. Price and quality are often synonymous, but more often it is scarcity, not value as food, which determines price. Those cuts of beef which are more sapid and tenderer, easier to cook and to chew, are more extensively sold at a higher price than the chuck and brisket, notwithstanding there is no commensurate difference in nutritive value. A highly prized article of food, one that is served on special occasions, is almost invariably an exotic one or one the scarcity of which makes it expensive. We rate its value not by calories, but by cost.

There is still another side to the influence of economic consideration in determining food habits. Those who produce food, the world over, are people of very modest income. Thrift is a necessity with most of them. If then, for example, potatoes are dear and turnips are cheap, the potatoes will be sold and the farmer's family fed on turnips. Holland, one of the principal dairying countries of the world, imports large quantities of oleomargarine, but sells her butter to England. The market value of what he produces is so high that the producer buys a cheaper substitute for himself. I have visited the homes of immigrant farmers in the Dakotas, where, notwithstanding that a considerable portion of the family income came from the sale of cream, no milk was given to the children. The reason, economic of course, is obvious. Every fresh cow meant a calf, which, if raised to maturity, had a definite cash value. The cream was separated and sold, the skim milk fed to the calves and young pigs. Children had no market value, nor any productive value until old enough to follow the furrows. Inevitably most such children grow to maturity with the idea that milk is suitable food for calves and pigs, not for humans, and thus a dietary habit (instinct) is created.

Modern commerce brings to our doors many things unknown to our grandfathers or, if known at all, were not considered as things to be eaten. Always, the introduction of a new foodstuff makes slow progress. Attempts have been made to force matters by laws or by royal decrees. It was so in Europe, following the discovery of America and the introduction of the potato. More food could be grown on an acre as potatoes than as wheat. The ruling classes attempted to compel the growing of potatoes, with resultant riots in France in the eighteenth century. Always in every land and every time, people are suspicious of new and strange foods. It is only epicures who are venturesome in trifling with the sense of taste.

Commerce in foodstuffs has been stimulated by the invention of new ways of packing, processing, preserving and handling them, until now it has become one of the major industries. Refrigeration in storage and transit brings to the table of middle-class families in New York beef from Argentina, bananas and avocados from the West Indies, oysters from Maryland and shrimp from New Orleans. Sterilization in sealed containers makes available throughout the year and at moderate cost seasonal fruits and fruit juices and green vegetables. The mere fact that these canned and bottled products are available throughout the year naturally stimulates their consumption, but availability is not the only, nor indeed the most persuasive factor. One needs only to pick up any current woman's magazine to see beautifully illustrated and alluringly worded advertisements for canned tomato juice, canned pineapple, peas, spinach and what-not. These advertisements always stress nutritive and health-promoting properties, but no one will believe that they are prompted by so altruistic a motive. Commerce and the desire for profit bid fair to revolutionize the eating habits (instincts) of the American people, whether for good or ill only the nutritionist can say. Unfortunately, to such a voice in the wilderness there are few hearers.

An extremely interesting example lies in the use of sugar. The first recorded description of sugar is to be found in the writings of Theophrastus, and even up to the middle ages it was considered as a medicine and sold by apothecaries. With the invention of cheaper and better methods of extraction and refining, sugar became cheapened until it could be used as a staple foodstuff. This gave a tremendous stimulus to the cultivation of the cane and the beet. Advertising and ingenuity in developing new confections and other dishes containing sugar now came into play in order to further increase consumption and profits. According to government statistics, the per capita consumption of sugar in the United States has increased from about 70 pounds in 1900 to 112 pounds in 1926. This latter figure corresponds to 139 grams or about 570 calories per person per day, about one fifth of the total energy consumption. What reliance, I ask, can be placed on an instinct which leads us to derive so large a fraction of our nutriment from the most highly refined carbohydrate known, a substance which builds no muscle or bone, yields no vitamins, and the excessive consumption of which is looked upon with grave suspicion by the medical profession?

Although sugar consumption has increased 60 per cent. since the beginning of the century, the total energy intake has not increased appreciably. We eat about as many calories per day as our grandfathers did. Sugar has replaced something else. Washington Platt has made a careful study of data collected from government reports and from other sources, and reports that during this same period the consumption of meat decreased 6 per cent., that of wheat flour and bread 30 per cent. and that of corn meal and flour 80 per cent. The consumption of fresh and canned fruits and vegetables has increased. Oranges have doubled in fourteen years. Dairy products have also increased, although they fell off sharply during the depression. It is a strange coincidence, and must be disturbing to those who hold to the reliability of instinct in the choice of food, that those products most intensively advertised should show increasing consumption, while those foods which have most largely nourished and sustained man for centuries, meat and grain, show losses. Is our eating ruled by preference or propaganda?

Finally, let us ask if the theory that man possesses an instinct which leads him to select those foods which most satisfactorily satisfy his needs is confirmed to any degree by the sciences of chemistry and physiology. These two branches of learning have by their union brought forth the young science of nutrition, which, using small laboratory animals as test-tubes has made quite substantial progress in the last quarter century. We know the importance of the fat soluble vitamins A and D, the first for growth and maintaining the integrity of the tissues, the second in the growth and development of normal bones. Vitamin A, or its precursor, an orange-colored organic pigment known as carotene, is especially abundant in carrots and green plants. The outer dark green leaves of cabbage and lettuce contain much more of it than the tender inner leaves. Furthermore, a considerable part of the carotene of plants is destroyed or inactivated in the process of cooking in an ordinary open kettle. Human taste apparently can not detect differences in this respect—we prefer white cabbage and lettuce hearts, and thoroughly cook all our greens.

Greenland was colonized by Eric the Red in 985, but in 500 years the people had disappeared. Study of skeletons recently disinterred at Herjolfsness by Hansen has shown evidences of marked rickets. Can it be possible that rickets, due to lack of vitamin D or calcium, or both, was responsible for the decline of this colony? A diet almost exclusively of grain would fail in calcium requirement as well as vitamin D. But the liver oils of many marine fishes are rich in the vitamin, and the Scandinavian peoples are notable fish eaters. The production and use of leafy vegetables would have supplied any calcium lack. A reliable instinct should have led inevitably to the use of greens and fish livers or liver oils, and saved the colony. It is the consensus of opinion that many people are obtaining less than optimal amounts of the water-soluble vitamins, yet sources of these are so abundant that a rational dietary instinct would lead inevitably to their selection.

Goiter is extremely common among the inhabitants of central North America, due primarily to iodine lack. Not having been accustomed to sea food, these people eat it but rarely, even though modern commerce has made it available. One would think that so outstanding a dietary deficiency would have produced a craving for iodine bearing foods and made fish and oysters even more popular than at the seashore. Although the iron and calcium content of agricultural crops may vary several hundred per cent., according to the type of soil on which they are grown, no taste can or ever could, detect the difference, and deficiencies of these elements in the diet in some localities are common.

Nor can I close without a word regarding certain misguided pseudo-scientists who are endeavoring to lead us in the choice of our food. Bernarr Macfadden, writing editorially in *Liberty* for January 25, 1932, said: "One can live on wheat indefinitely if the whole grain is used. It nourishes the body throughout its every part.'' And this, notwithstanding the observation of McCollum, of a number of years standing, that heifer calves fed exclusively on wheat and wheat straw failed to thrive. Alonzo Taylor has shown that war bread is actually more expensive than white bread as a source of available energy, because the excessive roughage speeds up intestinal movement to a point where absorption is very inefficient. The amount of indigestible roughage desirable in the human digestive tract has, according to Cowgill, rather well-defined limits. The fad for eating bran has nothing to commend it. I scarcely need mention that the idiotic teaching exemplified in the Hay system of diet that certain food combinations, such as meat with bread or potatoes, are harmful when taken together, has been exploded by more than one reputable scientist of recognized standing.

Finally, the theory that civilization has dulled our native instinct in the choice of food or rather that this dulling is resulting in less adequate nutrition is refuted by certain very pertinent statistics. The second and succeeding generations of immigrants to the United States from Central Europe or Japan are taller, have larger frames and are more robust than their parents. The higher standard of living, with its wider variety and choice of food, finds immediate response in the physical development of these people.

To summarize, I have tried to set forth that the dietary instincts or habits of man are an outgrowth of certain *mores* which had their origins in the beginnings of tribal life, influenced in their development by religion, by geographical habitat, by climate, by commerce, by modern industrial and inventive genius and by advertising. I have shown that food likes and dislikes are taught in childhood, and though they may be slow to change, they do change as influenced by the factors mentioned above, and that dietary instinct is only a distrust for the unknown or for those articles of provender for which we have not acquired familiarity. The contributions of chemistry and physiology to our knowledge of nutrition, valuable as they may be to the live-stock industry, have up to this time played a very minor part in directing the eating habits of the human species.

FUSIBLE ALLOYS

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FUSIBLE teaspoons have provided mirth for many. As the unsuspecting guest starts to stir his hot tea he suddenly finds himself stirring air with a stub of a handle, while the molten spoon mirrors his chagrin from the bottom of the cup. These "fusible" spoons are often thinly plated with silver to further allay any suspicions the guest may have. This humorous use of fusible alloys has been practised ever since the discovery of these interesting but forgotten alloys which melt below the temperature of boiling water. There exist, however, a number of more important and unique uses for these low melting alloys, most of which are dependent on the very low melting points.

Fusible alloys have been defined by Law[1] as alloys melting below the melting point of tin. The four common metals used in preparing the alloys are often themselves called fusible *metals* because of their relatively low melting points. They are listed below.

TABLE I

THE COMMON FUSIBLE METALS

Name	Melting point in degrees Centigrade
Tin	231
Bismuth .	271
Cadmium	321
Lead	327

To these four metals may be added mercury, which is often used to depress the melting point of the alloy still further.

It is indeed surprising that from combinations of these four metals, each alone melting above 200° C., it is possible to obtain an alloy which melts in hot water (from 70 to 100° C.). However, the phenomenon is a common one. Just as salt added to water lowers the freezing point of water, so bismuth added to molten lead lowers the freezing point of lead. This phenomenon will occur only if the two metals form neither compounds nor solid solutions with one another. The phenomenon is illustrated in Fig. 1 for two ideal metals A and B. As metal B is added to molten metal A, the freezing point falls along line AE. As metal A is added to molten metal B, the freezing point falls along line BE. The point E is the lowest freezing point attainable with any combination of metals A and B. It is known as the eutectic point. The composition of the alloy which melts or freezes at this point is known as the eutectic composition. Eutectic alloys are, therefore, alloys having the lowest melting points attainable with any combination of the metals concerned. If a third metal is added to the "binary" alloy a "ternary" eutectic alloy may be obtained with a still lower melting point. The addition of a fourth metal may produce a "quaternary" eutectic alloy with a still lower eutectic point.

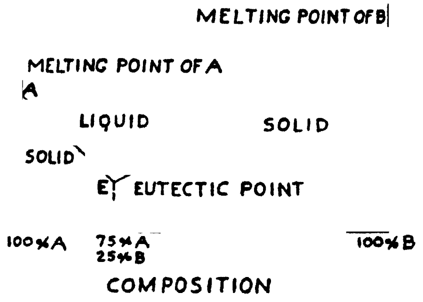

FIG. 1. TEMPERATURE-COMPOSITION DIAGRAM FOR AN IDEAL EUTECTIC ALLOY.

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[1] Law, "Alloys and Their Industrial Applications."

The various binary eutectic alloys of the four fusible metals have melting points ranging from 125° C. for bismuth and lead to 249° C. for lead and cadmium. The melting points of the ternary alloys range from 91.5° C. for bismuth, lead and cadmium to 145° C. for lead, tin and cadmium. Only one quaternary eutectic alloy is possible. It melts at 72° C.

History of the Fusible Alloys

Ternary alloys of lead, bismuth and tin melting in boiling water have been known for several hundred years. These alloys were usually named for their discoverers. Most of them were not eutectic alloys, and many of the reported melting points have been found to be erroneous. Table II shows some of the more common alloys, together with reported melting points.

TABLE II
Common Fusible Alloys

Name	Composition Parts by weight					Reported melting point degrees Centigrades
	Bismuth	Lead	Tin	Cadmium	Mercury	
Newton's metal ...	8	5	3			94.5
Rose's metal . ..	5	3	2			91.6
D'Arcet's metal .	50	25	25			91.6
Lichtenberg's metal	5	3	2			91.6
D'Arcet's metal with Mercury ...	50	25	25		250	45.0
Wood's metal	50	25	12 5	12.5		65.0
Lipowitz alloy	50	27	13	10		65.0

Robert Boyle[2] in 1662 mentions the use of an alloy consisting of bismuth two parts, lead one part, tin one part and mercury ten parts as a "fluid amalgam, which being moved backward and forward in a clean glass vessel leaves a train behind it, adheres to the glass and foils or silvers it. It is therefore used in foiling the inside of glass globes." While bismuth was not clearly distinguished from lead previous to 1737, it seems likely that Boyle recognized the difference. Rose's metal was first prepared by Valentin Rose the elder about the middle of the sixteenth century. D'Arcet's metal was discovered about the same time. It seems likely that the later alchemists used some of these fusible alloys in their attempts at transformation.

Black[3] in 1803 mentions Newton's metal, which becomes "fluid at a temperature something below that of boiling water." Black also mentions a proposed unique use of the alloy dissolved in mercury to "dissolve lead balls lodged in a wound" because "when dissolved in mercury it forms more fluid amalgams with other metals, particularly with lead than ordinary." He goes on to say, "whether this would answer the purpose I cannot positively say because the bismuth or part of it, separates in the form of a powder while the lead dissolves which might possibly prove inconvenient."

The use of cadmium to produce quaternary alloys melting below 90° C. did not come till some time after the discovery of cadmium by Strohmeyer in 1817. Wood's metal was first reported by Wood in 1869. For some time, it was considered to be the quaternary eutectic alloy. However, it has been shown by a number of recent investigators that Lipowitz alloy is more nearly of eutectic composition than Wood's metal. Melting points ranging from 60° C. to 80° C. have been reported at various times by various investigators for these two alloys. As a matter of fact, since the two alloys are so nearly of the same composition they should both melt at the eutectic point. The writer[4] has recently shown that these alloys do both melt at the same temperature. A number of recent investigations have placed the freezing point of the eutectic alloy at close to 70° C.

Uses of the Fusible Alloys

The uses of the fusible alloys have been many and sundry. Alloys rich in bismuth were early used in type metals and for making impressions of wood carvings. Bismuth gives to the alloy the property of expanding on freezing. Hence, sharp impressions are obtained.

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[2] Robert Boyle, "Treatise on the Usefulness of Experimental Philosophy," 1662 (about).

[3] Joseph Black, "Elements of Chemistry," 1803.

[4] S. J. French, *Jour. Ind. Eng. Chem.*, 28: 111–112, 1936.

D'Arcet's metal found early use for making anatomical molds. The metal was poured around the specimen and the fleshy parts of the specimen later dissolved out with caustic solutions.

Tin and bismuth alloys, because of the sonorous tones produced when struck, were often used in bell metals. Many of the alloys find use as low melting solders for tin, lead and pewter articles. Bismuth has even found use in the past as an adulterant of mercury. A number of the alloys have found use as baths for tempering steel instruments.

During the nineteenth century, a number of the alloys found use as safety plugs on high pressure steam engines. When the temperature reached a dangerously high point, the plug melted, releasing the pressure. However, since the alloys used were non-eutectic alloys, a gradual change in composition took place on long exposure to temperatures slightly below the melting point. The melting point of the alloy rose and the safety plug became a source of danger. The use of these plugs was soon discontinued.

In 1918 Steinmetz[5] suggested the use of eutectic alloys for calibrating thermal instruments, since the melting and freezing points of eutectic alloys are fixed and sharp.

One of the important modern uses of these alloys is for making seamless vessels. This was particularly important during the war, when gas tanks of unusual shape were needed for aeroplanes. The molten alloy is first made into the desired shape in a mold. Copper is then plated over the alloy to the desired thickness. The whole is then placed in a bath of hot water. The alloy melts and is poured out of the copper vessel.

The best known modern use is in the manufacture of automatic fire sprinkling systems. Openings in the pipe line at various intervals are sealed with metal stoppers held in place by a rod of fusible alloy. At a given temperature the alloy melts, releasing the stopper, and the sprinkler system starts. Fire doors are often held open by a bit of fusible alloy. On melting, the alloy releases the door, which closes by gravity. A number of other fire control and thermal instruments involve uses of the alloys.

PHYSICAL PROPERTIES OF THE QUATERNARY ALLOYS

Little published data have appeared on the physical properties of the quaternary fusible alloys. Budgen[6] has studied the tensile strengths, hardness, flexibility and grain structure of some twelve quaternary alloys. His results are summarized below.

The tensile strengths are rather low, being about one fourth that of copper and slightly better than that of tin. Elongation in the case of the eutectic alloy was 20 per cent. However, the elongation depended largely on the rate of loading. When 16.6 per cent. of mercury was present in the alloy, the tensile strength was greatly reduced. All the alloys split on gentle hammering or cold rolling. When loaded rapidly all the alloys possessed the property of extreme brittleness. When loaded slowly they were very flexible. In this respect, they resemble pitch.

Alloys containing the greatest proportions of bismuth showed the greatest degree of hardness. The Brinell hardness number of the eutectic alloy was 18, almost as low as that of pure annealed aluminum.

In grain structure the eutectic alloy and most of the others showed a fine-grained fracture. In micro-examination they showed the presence of four structural constituents, those approaching eutectic composition showing the finest crystals. All tended to corrode rather rapidly when kept molten under water or liquid paraffin.

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[5] C. P. Steinmetz, *Jour. Am. Chem. Soc.*, 40: 96–100, 1918.

[6] N. F. Budgen, *Jour. Soc. Chem. Ind.*, 43: 200–203T, 1924.

Other Fusible Metals

Mercury is the only other common metal of low melting point. It is sometimes added to quaternary alloys to produce quinternary alloys melting below 70° C. However, the products obtained are somewhat unsatisfactory. The tensile strength and hardness fall off rapidly. Melting points are rather indefinite. The alloy becomes pasty, then granular and hardens to a granular mass, losing much of the normal metallic property. Eutectic alloys are not formed

There exists another group of low-melting metals which because of their limited supply have not yet found use commercially in fusible alloys. These metals are gallium, indium and thallium. Table III shows a section of the Periodic Classification of the elements, indicating the positions and melting points of these rare metals together with the common fusible metals. Interestingly enough, all these fusible metals are found closely grouped in the periodic table.

TABLE III

A Portion of the Periodic Table Showing the Fusible Metals* and Their Melting Points in Degrees Centigrade

Copper 1083	Zinc 419.4	Gallium 29.75	Germanium 958	Arsenic 500(s)
Silver 960	Cadmium 321	Indium 155	Tin 231	Antimony 630
Gold 1063	Mercury – 40	Thallium 303 5	Lead 327.5	Bismuth 271

* The fusible metals are enclosed by the double line.

The rare metals gallium, indium and thallium are, themselves, of considerable interest. Because they are high priced they have found little use, and because they have found little use they are high priced. They are rather widely distributed, but few sources contain sufficient quantities to make the recovery economically practical with so little demand. As uses are found, the supply can be materially increased and prices decreased.

Twelve years ago, a gram of indium was unobtainable in this country. The metal was priced at ten dollars a gram (about $300.00 an ounce) with few purchasers. To-day, thanks principally to the work of Mr. William Murray,[7] indium is cheaper than gold. It can be purchased in small lots at one dollar a gram and in larger lots at considerably lower prices. Indium was first discovered in 1863 by Reich and Richter. Incidentally, Reich was a student of Strohmeyer, the discoverer of cadmium, and was looking for thallium when he saw the strong indigo blue line so prominent in the spectrum of indium. The element was named for its prominent spectrum line. The metal, itself, is soft and lustrous and remains untarnished in air. Alloyed with silver it gives an untarnishable surface.

Gallium was discovered by Boisbaudran in 1875 and was named in honor of France. It was found to be present in Oklahoma zinc blends in small amounts by F. G. McCutcheon in 1915. It is lighter than indium and somewhat harder and does not tarnish readily. It melts quickly when held in the hand and will melt on a hot summer day. It is still among the very rare metals, retailing at eight dollars a gram (about $240.00 an ounce). So far, it has found no industrial uses and has been but little experimented with because of its high price.

Thallium was first recognized by Sir William Crookes in 1861 by the bright green line of its spectrum. By 1862 he had isolated the new heavy metal resembling lead. The metal is soft and tarnishes quickly in air. It has found

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[7] S. J. French, *Jour. Chem. Ed.*, 11: 270–272, 1934.

few uses since the more abundant and stable lead serves most purposes better. Some is used in making refractive optical glass. Like lead, the metal and its compounds are poisonous. The use of thallium compounds in depilatories has resulted in some serious illnesses. The metal is the cheapest of the three by far, retailing at less than four dollars an ounce.

QUINTERNARY AND HEXERNARY ALLOYS

Quinternary and hexernary alloys, containing the three rare metals together with the four common fusible metals, have recently been prepared by the writer.[8, 9, 10, 11] Such alloys have not previously been reported in the literature, probably because high prices discouraged experimentation.

Thallium is not very soluble in the quaternary eutectic alloy and apparently does not form a quinternary eutectic alloy. However, the addition of some 6 per cent. of thallium to the quaternary eutectic alloy produces an alloy freezing at 66° C or about four degrees below the freezing point of the quaternary alloy. With further addition of thallium, the freezing point rises rapidly.

Indium appears to be completely soluble in the quaternary eutectic alloy. The melting point of the alloy falls rapidly as indium is added. The lowest melting point, 46.7° C., is obtained with an alloy containing 18 per cent. of indium. The alloy freezes sharply at 46.5° C. The sharp freezing and melting points, together with the type of cooling and melting curves obtained, indicate that the composition of the alloy comes very close to the eutectic composition.

The properties of the indium alloy resemble those of the quaternary alloy very closely. The indium alloy is, however, less easily corroded in air and water. Such an alloy, though more costly, has many advantages over the mercury alloy, since it retains its metallic properties

Thallium is but slightly soluble in the indium alloy, and eutectic hexernary alloys containing both indium and thallium together with the four common fusible metals are not formed. As a matter of fact, the melting points of such alloys rise rapidly as thallium is added.

Were gallium completely soluble in the indium quinternary alloy it should be possible to obtain hexernary alloys melting considerably below room temperatures. However, such does not seem to be the case While work on these alloys is still incomplete, the present evidence indicates that gallium is but slightly soluble in the indium alloy. The presence of about 1 per cent. of gallium lowers the melting point of the alloy about five degrees, to 41 5° C. Further additions have but little effect. More complete data on these alloys will be ready for publication soon. Gallium probably forms eutectic alloys with indium and zinc, for McCutcheon discovered the presence of gallium in the Oklahoma zinc ores by noting beads of liquid metal resembling mercury on the surface of a leady residue from the redistillation of zinc. On analysis, this liquid alloy proved to contain gallium, indium and small amounts of zinc.[12] An alloy containing 12 per cent. tin and 88 per cent. gallium has been reported melting at 15° C.[13] It seems likely therefore that a binary alloy of indium and gallium

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[8] S. J. French, *Jour. Ind. Eng. Chem.*, 27: 1464, 1935.

[9] S. J. French, "The Effect of Thallium on the Melting Point of Indium-Lipowitz Alloy," "Metals and Alloys" (in press).

[10] S. J. French and D. J. Saunders, "The Effect of Thallium on the Melting Point of Lipowitz Alloy," "Metals and Alloys" (Jan., 1936).

[11] Unpublished data obtained by the author.

[12] "Gallium, Germanium, Indium and Scandium." Information circular 6401, U. S. Bureau of Mines, November, 1930.

[13] N. A. Pushin, S. Stepanovic and V. Stajic, *Zeits. Anorg. Allgem. Chem.*, 209: 329–34, 1932.

could be prepared melting below 0° C. The cost of such an alloy would be prohibitive. From the evidence reviewed it seems unlikely that gallium would form a quinternary eutectic alloy with the common quaternary alloy

POSSIBLE USES OF QUINTERNARY AND HEXERNARY ALLOYS

While these very fusible alloys containing indium and gallium are too new to have any commercial uses as yet, great interest has been manifested in them. It seems likely that they will find their greatest field of usefulness in thermal controls of various types.

Since the melting point of the indium alloy is so little above normal body temperature such an alloy may find use for making casts or impressions of features. The body can come in direct contact with the molten metal. Sharp finger print impressions can be made in this manner. The alloy after hardening can be plated with copper, then melted off for further use. The use of the alloy for such purposes will depend somewhat on the expansion or contraction of the alloy when it freezes. While these properties have not yet been fully determined, superficial examination indicates a slight expansion on freezing. To obtain alloys melting down to body temperature, small amounts of gallium or mercury may be added.

Alloys melting a little above body temperature might also find use in surgical casts. For this purpose the alloy would have to be impregnated in a cloth matrix. The warm flexible material could be wrapped around a broken leg or arm and allowed to set. If it were desired to change the position of the member, hot water bottles would melt the cast and permit the change to be made.

Until the prices of the rare metals are still further reduced, uses of the alloys will be restricted to fields in which cost is of small importance or in which the alloy may be used over and over. In small lots, the indium alloy costs, to-day, close to five dollars an ounce. One per cent. of gallium added raises the cost to more than seven dollars an ounce. The more common alloys melting above 72° C. cost, for the ingredients, less than ten cents an ounce. Little is known, as yet, about the physical properties of the quinternary or hexernary alloys.

IN QUEST OF GORILLAS

XI. GORILLA CHILDREN

By Dr. WILLIAM KING GREGORY

CURATOR OF COMPARATIVE ANATOMY AND OF ICHTHYOLOGY, AMERICAN MUSEUM OF NATURAL HISTORY, PROFESSOR OF PALEONTOLOGY, COLUMBIA UNIVERSITY

UPON returning to Yaoundé we called at once at the American Protestant Mission and found that, although Mr. and Mrs. Johnston were then away, they had left a very kind letter for us, inviting us to stay at their home and to return there whenever we happened to be in Yaoundé. The Negro steward of the Mission then showed us to two very pleasant guest rooms and our own three "boys" (two of whom had been Mission boys, recommended to us by Mrs Johnston) went into the kitchen and prepared our meals. Through the windows and door of the dining room we could look down past the well-kept flower garden over a fertile valley to the bold lumpy hills in the distance. We thought it spoke very well for the good influence of the Mission that Mr. and Mrs. Johnston could go away for several weeks and leave everything apparently wide open and solely in the care of their Mission boys. Moreover, as far as we could see, the church services, schools and farming work were going on quite according to schedule.

Early the next morning I heard the measured sweep of a Presbyterian hymn tune rising steadily from the chapel near-by—an ancient Protestant hymn sung with strange accents and exotic voices but with great sincerity by black men who sensed its dignity. No wonder the good missionaries loved these people as their very own. I could not help contrasting the order and decency and sanity of the Mission and its churches, hospitals, schools and farms with the miseries of witchcraft, fetishism and cannibalism and with the unspeakable abominations that used to be practised in this part of the world when a great chief died and hundreds of people were sent with him into the grave. Even now perhaps this Eden is not without its serpent. Some day jealous ambition may dethrone the benign rule of the French government and of the missionary, a republic or a soviet may arise and the sordid history of Liberia may be reenacted But at present the terrors of barbarism have been suppressed, and the corrosive evils of civilization have not yet devastated the people; peace reigns, the happy children play jackstraws, mother toils patiently in the garden and father lolls in the sun What next?

After we had purchased supplies at Yaoundé we set out for a village called Vimeli (Mbalmayo) about fifty miles south of Yaoundé, where gorillas had recently been reported.

It was early in the dry season and therefore the best time for the repair of the roads. Consequently, in many of the villages that we passed perhaps thirty or more people, mostly women and children, were engaged either in bringing small baskets of earth and gravel to throw down on the road or in clearing the ditches. As we rolled along the well-made roads bordered with oil palms, the folks working there proved hardly less responsive to a smile and a wave of the hand than the people of the Congo. Our quiet-voiced and meek-mannered cook Zé had brought in his hands his prized possession, a large mirror in a gilt frame. He was sitting on the baggage behind me and once in a while he would hold up the mirror rather shyly so that the women and children on the road could see their reflections in it. This never failed to bring smiles and a buzz of

Photograph by H C Raven

MENDING THE ROAD.

approval. Several times we passed chiefs who were out inspecting the work of their people on the roads. One of them was attired in a complete English riding habit and sat astride a very smart-looking horse; but his attendant was holding the bridle. Such a display of superiority in Africa makes everybody feel better; the owner's breast swells with pride and the people feel that a king has spoken to them. From the presence of the chiefs and of a policeman now and then we suspected that the people were not at work on the roads through any large-minded interest in the common weal but simply to free themselves from imprisonment for non-payment of taxes

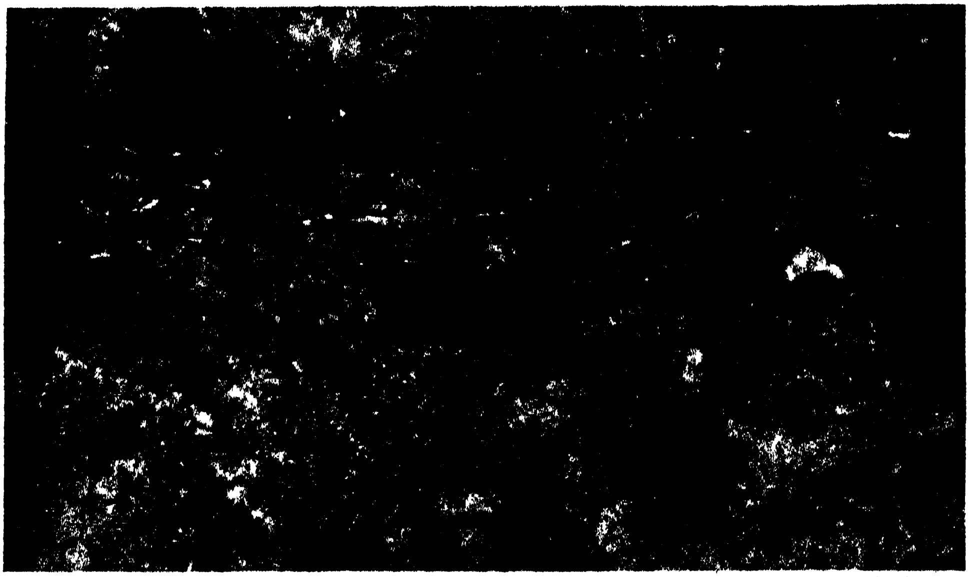
After a morning's ride through a more or less forested country we arrived at Vimeli and were most kindly received by M Guillot, the *Chef de Poste,* who courteously invited us to share his residence with him. His house, or group of houses, was set in the midst of a large open plaza covered evenly with fine gravel. He gave us an immense high-ceilinged room, where we set up our cots and lived very comfortably The square house was supported by a single high umbrella-tree in the middle, with wooden posts at the corners No nails were used, the parts being bound together with twisted strands from the oil-palm leaves. The walls consisted of a system of interlaced uprights and horizontals like the ordinary native houses and for which the oil-palm likewise furnished the materials. The roof was covered with many layers of the immense folded-up leaves of the oil-palm and was practically rain-proof except at one small spot.

While lying in bed and looking up at the rafters of this house I realized that the native builders must have employed at best only the simplest methods of measurement and calculations. Dr. James Chapin informs me that during his long stay among the Mangbetou and other native tribes of the Congo he and Mr. Herbert Lang took considerable pains to find out how the natives made measurements in planning their houses. He said that they would take a stick of convenient length and lay off the distance so many times along each side of a parallelogram, but that they had no standard stick for measuring, and his own measurements showed that they did not build the walls strictly at right angles to each other, although in constructing a circular house they knew how to describe a circle with a post for a center and a piece of fiber as a radius. In short, native Negro architecture and indeed their entire culture seems to be based on empirical methods rather than on precise measurements and calculations Anyhow, our house at Vimeli was just as cool and comfortable as one could reasonably desire.

M. Guillot was a delightful companion and we learned from him much that was of value and interest about the natives and the natural history of the region As *Chef de Poste* he acted as chief magistrate, and his court was crowded with people accused of minor offenses or seeking divorces or redress. Many difficulties arose from the inflexible opposition of both Catholic and Protestant Missions to bigamy and polygamy. When a man became a convert he had to give up all but one wife; but what was to become of the other wife or wives? We learned elsewhere that sometimes the cast-off wife would work in the fields for the Mission, but that her ex-husband would regularly call and take away her wages, apparently to repay him for the money he had invested in buying her from her parents. We heard also that some natives tried to be both Christians and polygamists at the same time. One can imagine that to the native man the chance to escape hell-fire and attain eternal bliss must at first seem well worth the price of a wife or two, even though each wife represents a big investment in cows or other goods and chattels, but practical difficulties arise when he has to decide which wife to part with And probably the wives themselves are not altogether silent while the decision is being made Thus one can also understand why the French Government is said to discourage the

Photograph by H. C Raven

RESIDENCE OF THE *CHEF DE POSTE*, VIMELI.



From a motion picture by J H McGregor

DRIVER ANTS.

divorcing of second wives, and no doubt many quarrels, lawsuits and acts of violence must result from the turning out of helpless women from their own households.

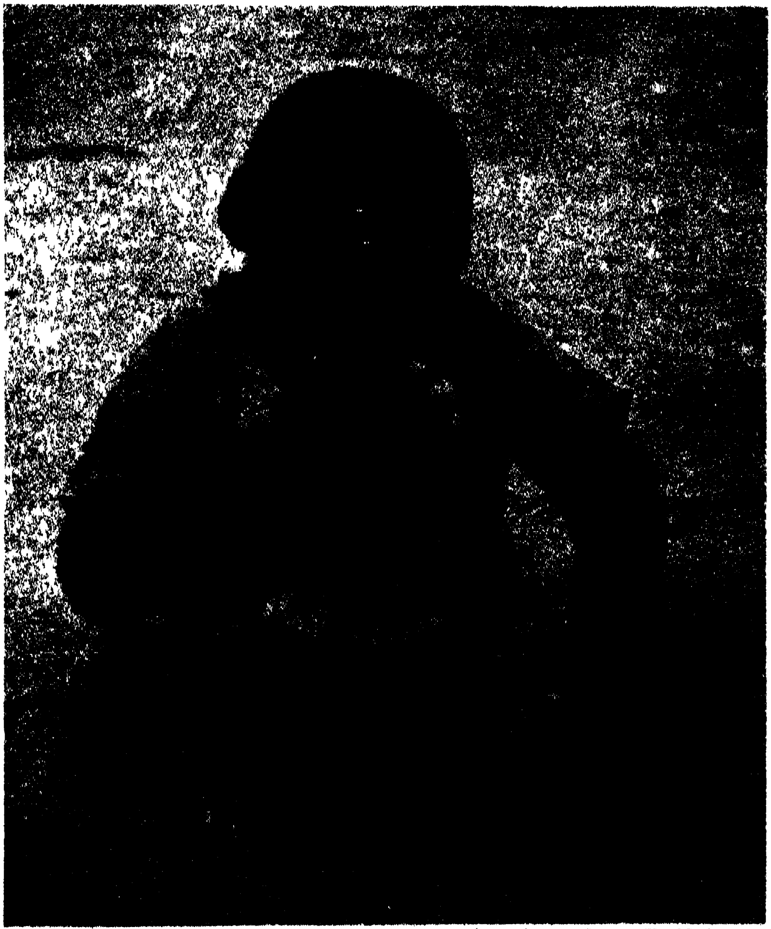
At M. Guillot's I met two gentlemen who were connected with the French medical campaign against the sleeping sickness From them, as well as from official reports I learned that in recent years many villages had been almost wiped out by this disease, but that, after the sterilization of the dead and immunization of the living by the traveling clinics, the mortality in a given district in the following year was greatly reduced. In some districts the organisms responsible for the disease had even been eradicated so that the tsetse flies were no longer infected and were consequently harmless.

The main square of Mbalmayo (the name of the town on the railroad, Vimeli being, as it were, a suburb of the town) offered a lively scene on market days, when rival shops employed barkers to yell at the natives, trying to persuade them that "our shop pays you the highest prices and sells the best goods at the lowest prices." But the natives, who had bombarded each other with verbal uproar all their lives, did not appear to be much influenced by the high-pressure selling agents. Here again no tongue or pen or camera could adequately convey the diversity and the comicality of these black folk.

The railroad at Mbalmayo was literally of pygmy size, with toy engines puffing about and blowing shrill little whistles. Down by the river the camions came to transfer great sacks of produce to tenders on the river. Here a ferry, comprising several large canoes, carried passengers across, while another ferry for autos was provided a little way up the river.

Two big canoes at this place were equipped as house-boats. On one of them a very large powerful young woman of the big forest-Negro type was preparing food; several of the men on shore seemed to belong to the same big race.

The smooth river gave back most attractive reflections of the opposite bank, and as one approached the other side in a canoe he saw an elaborate drapery of long vines with the sun streaming down through the very high trees. The forest, although now ruined by the natives, except along the river bank, had evidently been of the general Congo type and doubtless had once harbored many chimpanzees and gorillas



From a motion picture by J H. McGregor

ALFRED.

During my walks around Vimeli I noticed that the very numerous umbrella-trees, in which the leaves are of the compound pinnate type, had grown up from a small bush in which one can trace a series of leaves of progressively complex form, beginning at the bottom with a more or less heart-shaped leaf with two projections, and passing through leaves with serrate margins to the greatly subdivided leaf of the sapling and fully grown tree.

One afternoon I heard music issuing from a drum and a xylophone in rapid march time, thus.

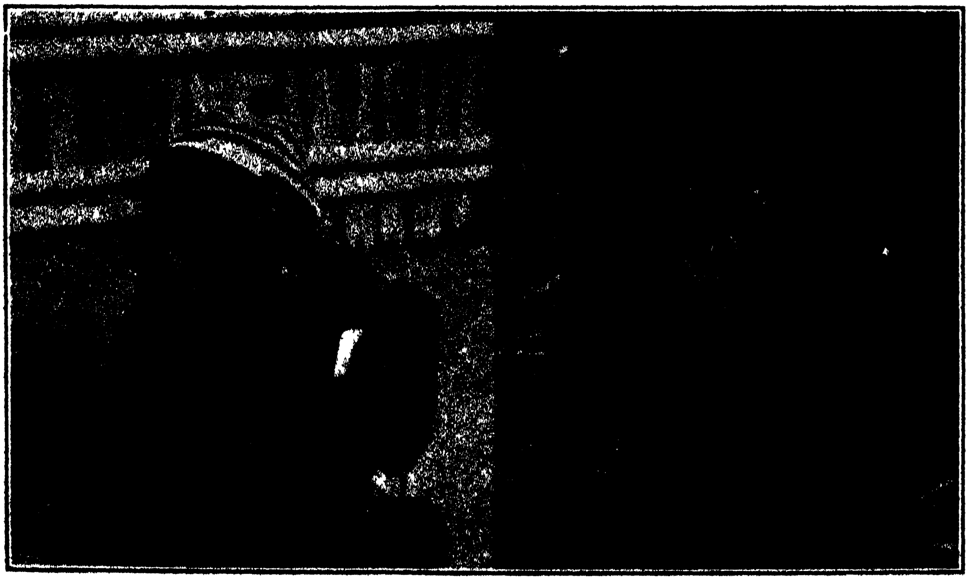
POM, pom, pom, pom;
POM, pom, pom, pom;
Pómpernickle,
Pómpernickle,
POM, POM.

On one of my walks I came across two great streams of driver ants, which were transferring their pupae across and

From a motion picture by J H McGregor

ALFRED AT PLAY.

under the railroad track They had excavated a deep groove, which was in some places almost a tunnel, extending down a steep embankment across the hard clay ditch and path, under the ballast of the track, across the clay path on the other side, into the thick jungle. They had tried to cross the track over the rails, but possibly after some disastrous experience with a train had abandoned this path and gone through the ballast under the rails Untold thousands of workers streamed in one direction, carrying the pupae in their jaws, suspended beneath their bodies. Both sides of the tunnel were guarded



JACQUELOT. From a motion picture by J. H. McGregor by aggressive soldiers with huge mandibles. These stood in hundreds, rearing up on their hind legs, with their jaws in the air. At several places the soldiers were massed in a living lattice-work above the open groove. When I crept up with extreme caution the warriors became only vaguely uneasy and did not know which way to rush toward the foe. Hence, being well guarded with heavy shoes and puttees I was able to flick off the few that chanced to find their way above the soles of my shoes When I blew down on the mass the pandemonium among the soldiers was intense, as they rushed out in all directions seeking the offender, but the workers streamed on with their burdens A grasshopper that I dropped into the middle of the pathway was hustled out of the way in a few minutes.

After I had had a good look at the ant army, I hurried home to tell McGregor, who had been seeking for just such an opportunity to get motion pictures We immediately got the apparatus together, and he succeeded in getting many close-up views with a strong lens. McGregor went in shorts with bands of cotton around his legs He was so intent upon getting good pictures that he allowed several of the soldier ants to get past his defences. Being an ardent entomologist, however, he allowed a few to bury their big mandibles in his skin; then he merely picked them off and would have preserved them if it had been practicable. Twenty-four hours later we went again to get more pictures and the procession was still going; but on the third day it had vanished.

Near the market-place at Mbalmayo there was a Greek merchant who owned a young captive gorilla, the liveliest specimen of his kind we had ever seen. On market days "Alfred," as he was called, stayed in front of the shop, romping with a little boy or held in the arms of one of the employees. The natives coming to town with their produce were much amused by his antics, in which he reminded one of a chimpanzee rather than a gorilla Alfred was most dexterous in hanging on to the post with one hand and two legs while holding a can of milk in his other hand. In drinking from the can, however, he was not particular about how much milk he spilled on his jumpers If excited or especially interested in anything, he would rapidly beat his chest with his hands after the manner of adult gorillas.

From a motion picture by J H. McGregor

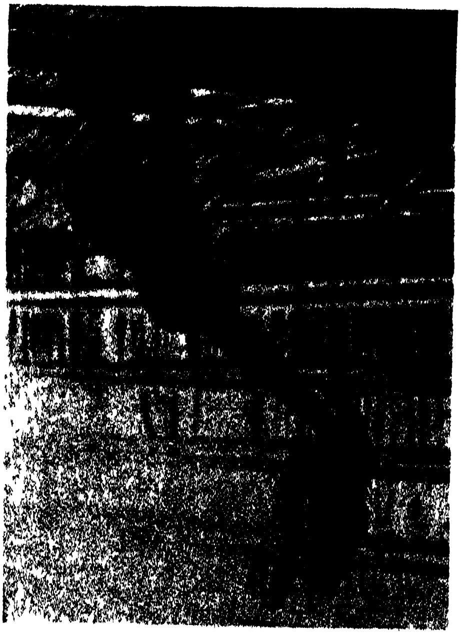
JACQUELOT AND KITTEN.

From a motion picture by J. H. McGregor

MONGOOSE GETS NONE.

From a motion picture by J. H. McGregor
HAND OVER HAND

M. Guillot also owned a baby female gorilla about eighteen months old and a number of other pets, including a parrot and a mongoose. The little gorilla was in excellent health and had the freedom of the house and environs. Most of the time she would sit quietly on the ground with her legs bent and her hands free to handle things—including the kitten. She was very deliberate but also very expert and adroit in all her movements. For instance, if she were eating a cracker and the mongoose came up and tried to snatch it, she would simultaneously turn her head away and push him away with one elbow, so that he had to make three or four sudden dashes before he could snatch even a piece of the cracker. In going after a bunch of bananas suspended from a horizontal support of the roof, she would climb up the vertical post by clasping it with hands and feet much as a native would climb a tree; then she would crawl along the under side of the horizontal beam, also grasping it with hands and feet. At such times the stresses on all the digits and especially on the thumb and great toe must have been exceptionally great.



From a motion picture by J. H. McGregor
REACHING FOR THE PRIZE.

Sometimes she would swing over to the vertical wire and then down to the bunch of bananas, holding on by one hand to the horizontal above and hugging the bunch of bananas with her body, legs and one hand. She would break off a banana with the free hand and hold it up to her mouth, then begin to strip the skin from the fruit. If she got tired holding on by one arm above her head, she would reach up with the other arm and release the tired one. When eating sugar-cane she held it by one hand and made very uncouth motions with her lips, almost like a human child.

She used her hands to handle things with and her feet to cling with, and it was evident that in this young gorilla the differentiation of function between the hand and the foot, which culminates in the human stage, is already under way, in spite of the fact that when walking on the ground the fore part of the body is supported by the knuckles of the hand. So too in the young gorillas now living in New York, Philadelphia and Washington, any one may see that the hands, in spite of their present use in locomotion, are also used as true hands and that their feet, at least normally, are used not for the delicate manipulations of objects but merely to grasp with or for support in walking

After a week of intensive but unsuccessful hunting in the country centering around Vimeli, Raven found that although gorillas had frequently been killed in that neighborhood they were not sufficiently in evidence there at that time to warrant further expenditure of time; so he decided to go back again to Yaoundé. Accordingly, after three days' delay, due to the failure of a certain camion to reach us on the day agreed upon, we took leave of our good friend and host, M. Guillot, loaded our equipment, our boys and ourselves on a camion and left Vimeli.

We carried also another passenger, the little gorilla, which McGregor had purchased from M Guillot. She screamed terribly when shut in a large box behind wooden slats, but was somewhat comforted when McGregor sat near her and handed her bananas and oranges during the trip to Yaoundé

On returning to the Mission at Yaoundé McGregor secured some excellent motion pictures of two young gorillas owned by Mr. Johnston. The larger one, "Bushman," was about three years old and in vigorous health. The small one, still a baby, was also in excellent health but less rough and aggressive than Bushman. Both would rush after their black nurse and, grasping his legs, would ride along on his feet as he moved thus handicapped. This clutching habit seems

From a motion picture by J H McGregor

EATING SUGAR-CANE.

From a motion picture by J H McGrego

STUDY IN HANDS AND FEET

to be congenital in both young gorillas and chimpanzees and may be of value in preventing them from getting separated from their mothers or nurses.

During our several visits to the American Mission at Yaoundé McGregor took a lot of other motion pictures of the little gorillas, Bushman and the baby, together with our own little gorilla. It was very amusing to watch the behavior of these three small gorilla children when playing together. All three seemed to recognize their own kin and betrayed no fear of each other. Bushman, being the oldest, largest and most aggressive, would sometimes grab our little one by the hind leg and start to drag her around; she would push him away with her elbows and try to bite him. When she went under a bench he would follow and be very rude and rough. She would retreat and sit down in the sunshine, and soon his easily diverted mind would be on the trail of another idea and he would try to push himself through a big hole in the wall. In running about the young gorillas already swung their long straight forearms back and forth and stepped outside of their right hands with their left hind feet, after the manner of adult gorillas.

When the time came to leave we went down to the shops to purchase boxes and wire netting with which to make a cage. Raven made a fine one, light and strong, with nice straw on the bottom, but our little gorilla screamed like a baby when she was placed in it and exhausted herself in vain efforts to push through the netting.

McGregor and I then made ready to return home. We all hated to break up our pleasant fellowship in the field and we should not have left Raven if we could have substantially furthered the main business of getting gorillas or have been really useful to him in his field work. But he felt very confident that by taking a camion farther into the interior and away from the big towns he would be able to get his two gorillas in a short time and to return home soon after we did. Moreover, he intended to make his headquarters at the medical mission at Dja-posten, near the Gaboon border, where gorillas were reported to be numerous and where he would be in close touch with our friends, Mr. Harris and other American missionaries.

A camion was solemnly promised for five o'clock next morning so that we could catch the train for Douala, leaving at 6 20 A. M But five o'clock and even five-forty came and still no camion, and we and our baggage were over a mile from the station. Also if we missed this train we would inevitably miss the boat sailing from Douala on December nineteenth. In desperation we got our own boys and as many others as we could commandeer to put our pieces of baggage on their heads and start on the trek to the station. Our promised camion never appeared, but on passing through the village we heard another camion just being started on its way. We rushed up, told the driver our predicament and in a few moments were rolling down the long hill, sounding our horn to part the leisurely gangs of pedestrians. We arrived at the station in the nick of time, and the French stationmaster enjoyed screaming at the poor black ticket agent, who was patiently trying to calculate the tariff on our extra-weight baggage and to compute the other items which make their railroad tickets look like hotel bills.

As the train pulled out from Yaoundé I could not help feeling uneasy and even guilty at leaving Raven alone, but in a lifetime of exploration being "on his own" was his normal state, and Africa had been kind to us so often that none of us could have anticipated what was to happen Meanwhile our poor little gorilla was screaming in the baggage car with a peculiarly disturbing and baby-like cry and would not be comforted by oranges, bananas or sugar-cane. At every station her screams rang out and stopped only when we put our fingers through the wire netting for her to clutch tightly. Our hearts sank as we foresaw the difficulties of the long voyage home, but it was too late to retrace our steps and all we could do was to visit and try to quiet our little ward at every stop.

All that day as we passed through the

From a motion picture by J. H. McGregor

LET ME ALONE.

From a motion picture by J. H. McGregor
"BUSHMAN" RUNNING.

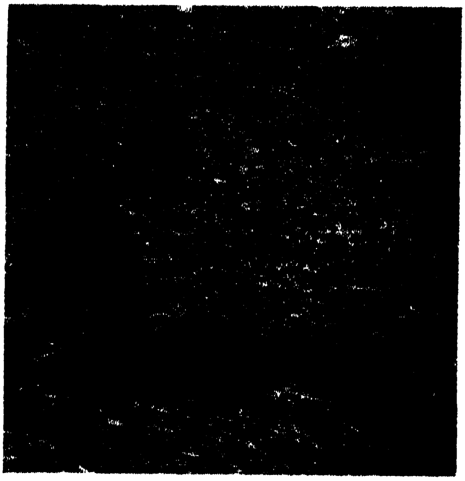
Congo forests we gazed intently at it, realizing that this was our last chance to do so, at least on the present expedition Again I regretted my lack of botanical knowledge, which might have given me some slight clue to this grand, chaotic battle of competing organisms. For the first time in my life I became aware of the very elementary fact that the height of any straight tree trunk must be an expression of the differences between two opposite forces continued over a long period of time: first, the universal downward pull of gravitation, and secondly, the upward thrust of an evenly balanced circle of live tissue growing up toward the light. But exactly how was the upward growth-pressure produced? Why did not the sap leak out through the roots, where the water was taken in? In other words, what held the column of water in place against gravitation? And why did the centrifugal or lateral pressure, which gave rise to buds and branches, produce such widely different results in different kinds of trees? I was so much interested in these queries that I forgot to feel ashamed that I had to go to Africa to become aware of their existence.

We arrived at Douala that evening and passed a busy following day doing some necessary shopping and securing a certificate of immunity from the organism of sleeping sickness, without which we could not purchase our steamer tickets. At the laboratory where we were examined a French doctor took our records, while a black assistant skillfully extracted a drop of blood from our fingers and prepared a smear for microscopic examination. From an official report on the subject I learned that before the traveling hospitals are sent out to fight the sleeping sickness the black assistants are taught to be skilful technicians, that they learn to make excellent microscopic preparations and can be trusted to make faithful and accurate reports as to the significant facts revealed by the microscope After securing a clean bill of health we purchased our tickets and repacked all our baggage ready for our departure at six the following morning.

That evening as we sat at dinner in the hotel a splendid big rhinoceros beetle came flying into the dining-room. Its flight was very clumsy, and its heavy black body and reddish wings gave it the appearance of a flying toy. I made an ineffectual attempt to catch it, but the waiter knocked it down and I then caught it in my handkerchief. Seizing it by the back I marvelled at its strength and at the curious way in which the tip of its great backwardly curved horn could be opposed to a crotch-like branch that grew out from its neck-plate. But as we had no means of preserving it, I set it free.

One of the idiosyncrasies of many African hotels is that, as the managers and waiters have to stay up till very late serving refreshments to customers, they are mostly dead to the world early in the morning, so that the guest departing on the only outgoing train or boat of the day, which usually leaves around six in the morning, can get no breakfast and is lucky if he can bribe some boy to wake him in time. On the morning of the day of our leaving Africa I awoke at 4:00 A. M. and, being afraid to go to sleep again, got up and dressed. At 4:30 A. M., an hour and a half before we needed to leave the hotel, a black boy came to wake me So I passed the time in looking out the window, watching the brilliant stars, the tree frogs and the fruit bats. Shortly before six McGregor and I (having sent most of our baggage down to the wharf the afternoon before) took a few boys from the hotel to carry our remaining baggage and walked down a few blocks to go on board the tender, which took us down the long estuary to meet the *Asie* Meanwhile our little gorilla had been very content, sitting on the lap of a black boy whom we hired to look after her day and night

So we went up on board the big steamship and thus our share of the African expedition was practically finished. A few days later, after leaving Dakkar, we veered away from the African coast Here at Cape Verde the continent was slowly giving back before a furious attack of the ocean. Through our field glasses we could see immense waves boiling against the rocky cliffs and rushing through narrow openings in the rock. In some places the waves had worked their way into the cliff from opposite sides, first tunnelling it and finally cutting through the arch above the tunnel, so that separate islands now stood as outposts of the main mass. As this grand scene faded from view a troop of friendly dolphins came out to speed us on our way, and that was the last we saw of Africa



From a motion picture by J H McGregor

GORILLA BABY RUNNING.

(*The next two sections, entitled respectively, "Hunting Gorillas in West Africa" and "Men, Gorillas and Sleeping Sickness," by H. C Raven, will conclude the series.*)

EARLY PHOTOGRAPHY IN THE MEDICAL SCIENCES

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PHOTOGRAPHY is of particular value to the scientist because it has two characteristics which no other method of reproduction possesses. It produces an accurate and impartial record of the field upon which its lens is trained, and it permits seizing and rendering permanent the more-or-less evanescent changes that ordinarily occur too rapidly for complete study. These valuable properties of the photographic camera have such wide application that inspired hands from all fields of science have worked toward the perfection of the chemistry and physics of this scientific tool In the medical sciences there has been need of special photography for particular purposes, and ingenious devices for photographing almost inaccessible parts of the body have been developed. To-day specialized photographic apparatus for medical purposes has reached a high degree of perfection, and it is possible to photograph such fields as the interior of the stomach or the retina of the eye with such good results that the photograph secured is perfect enough to form the basis of an accurate study or diagnosis.

This perfection has not come immediately, but has been the result of much work and experimentation. The development of photography as applied to medical sciences before 1900 is especially interesting because in that period of its development all the fundamental methods were invented, and although there have been many improvements since, both in cameras and emulsions, the ingenious devices invented by these early workers have been the basis for the successful medical photography of to-day.

Photography has served medical science in two ways. First, it has been a research tool, and as such it has been used to make records for detailed studies. In the clinic, for example, visual examinations can not always be accurate and complete, and so photography has been employed for making permanent records from which careful studies and comparisons of a condition at different times can be made. It has also proved valuable to the physiologist, who used it with great success as a means of recording physiological function with the photographic kymograph. The second use of photography is in the illustration of original scientific findings and in teaching. Here it is used to supplement or replace verbal descriptions. The availability of photography for this purpose depended, of course, upon the invention of inexpensive and efficient engraving methods in order to achieve quantity reproduction. These methods lagged behind the development of photography, and thus, as new photographic procedures became available, it was not always possible to take full advantage of them. Photolithographic methods found some use in the reproduction of photographs, but it was not until the invention of the half-tone engraving method in 1882, by George Meisenbach, that a really efficient and inexpensive means of quantity production was available.

There were, however, some publications before the invention of photoengraving which contained original photographic prints. In 1877 Bourneville[1] published an excellent volume containing over 50 prints made directly from negatives taken by Paul Regnard of mental patients in the hospital of Salpêtrière. The results were highly satisfactory, and some of the photographs reproduced in this book serve their purpose beautifully. In two subsequent volumes by the same authors, lithographic methods were used to reproduce the photographs. By means of these photographs and the detailed case histories contained in these volumes it was possible for the student or practitioner to learn a great deal. Some of the early atlases of pathology and skin diseases were also illustrated with photographs and serve to show what could be done with photography along this line. The wide-spread use of treatises of this nature was hampered, however, more by the restrictions of the manifolding processes than by the photographic difficulties of the time.

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[1] The first of these three volumes, entitled "Iconographie Photographique de la Salpêtrière," was published in 1877. Two subsequent volumes were published in 1878 and in 1879.

PHOTOGRAPHIC KYMOGRAPHS

The inherent characteristic of photography—its ability to stop motion, and thus seize some segment of time to hold it fixed and available for a leisurely, accurate study—has been used with the greatest effectiveness in the analytical studies of motion. Jules Marey in 1885 used photography for the analysis of movements in man, animals and birds. For part of his work he made a series of exposures on the same plate, which resulted in a composite photograph showing successive positions of an individual performing such commonplace acts as walking, running or jumping By taking a series of pictures in rapid succession he obtained a similar result, and these experiments, with the work of Muybridge, the Lumiere brothers and others, formed the foundation of the modern motion pictures.

It is frequently of great value for the physiologist to be able to record in some permanent fashion the physiological changes that take place so quickly that they can not be studied directly with any degree of accuracy. For example, a single heart beat takes place in less than a second and can not possibly be studied directly. This was partially solved by Chauveau and Marey in 1863, the heart writing a record of its contraction through a system of levers upon a smoked paper. This was a great contribution to

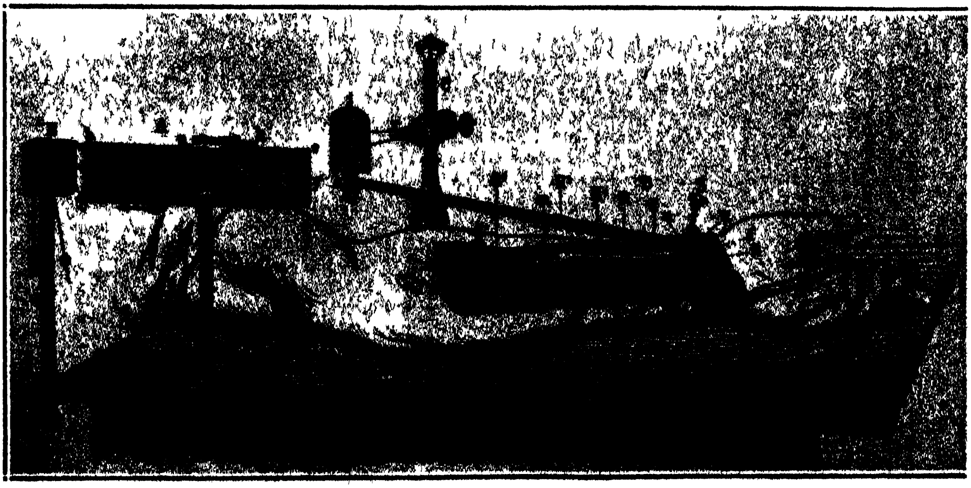

FIG. 1. THE PHOTOGRAPHIC METHOD OF RECORDING THE PULSE WAVE DEVELOPED BY STEIN FROM MAREY'S SPHYGMOGRAPH IN 1885.

physiology because it gave experimenters a means of accurately studying the function of organs. But it had the disadvantage of losing many of the delicate features of physiological function in the comparative crudity of the levers and mechanical contrivances which translated the function into a graphic record upon the smoked paper. To overcome this difficulty photography has been used with great effectiveness. The plate in a cassette, or photographic paper on a kymograph drum, is moved rapidly behind a slit in a light-tight box, and the record made with the aid of light. Fig. 1 shows the arrangement used in 1885 by Stein for recording the pulse wave photographically. This arrangement did not differ markedly from Marey's sphygmograph, in which the pulse wave was recorded on smoked paper. The record was made with a beam of light passing through the perforation in the screen to the photographic plate as it was drawn past the slit This photographic method of recording did not have any very great advantage over the usual smoked paper method. It eliminated the friction of the writing point against the smoked paper, but did not overcome the greatest difficulty, which lies in the mechanical losses of the lever system

The value of the photographic method of recording lies in another arrangement by which most mechanical losses are practically eliminated. This method was foreshadowed by Czermak in 1863, when he demonstrated the pulse in his lecture room by allowing the sun rays from a heliostat to fall upon a thin plane mirror lying on an artery. The mirror reflected the rays of light upon a screen, and thus the pulsations, greatly magnified, were made visible. He suggested the use of a moving photographic plate for making permanent graphic records of the movements.

Such an arrangement has been used by Wiggers in his work on endocardial pressures. In his optical manometer an arrangement was used which transmitted the endocardial pressures to a diaphragm which actuated a small mirror. A beam of light falling upon this mirror and reflected to a moving film made a graphic record of the changes in pressure. This method was so far superior to the mechanical methods that had been used previously that for the first time the conditions of pressure inside the heart and large blood vessels were understood.

Variations in pressure can also be recorded by another photographic method. Tissander in 1874 described in his book on photography[2] a method of recording temperature or barometric pressure by allowing the shadow of the mercury column to fall upon a photographic paper moving behind it in a light-tight box. This method is the most direct way of measuring variations in pressure and has been used widely for types of work in which delicate changes in pressure must be recorded, such as measuring intra-ocular or intra-cranial pressure or for recording changes in volume in plethysmographic work The principal loss from the inertia of the fluid is small, and since there are no other losses even the most delicate fluctuations leave their mark upon the photographic film or paper.

The general arrangement used for making recordings of this sort was to enclose the drum carrying the photographic paper or film in a light-tight box, on one side of which was a slit under which the film or paper passed. A glass tube of uniform bore was placed over the slit, and if the liquid within the tube was opaque, like mercury, a record resulted in which the lower half of the paper or film was unexposed, the light from the exterior being interrupted by the mercury. If water was used, the rays of light were brought to a sharp focus by the water, and this part of the paper or film was much darker than the portion covered by the tube containing air which diffused the light. In some cases a drop of an immiscible liquid, containing a dye which interrupted the light, was made to float on top of the water column, thus more sharply delineating the two areas.

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[2] "Les Merveilles de la Photography," by Gaston Tissander, Paris, 1874.

The study of action currents has been accomplished almost entirely with the aid of photography, which was used in early investigations to record the fluctuations of the mercury meniscus of the capillary electrometer. As early as 1878 Marey described methods of photographing the fluctuations of the mercury meniscus in the Lippmann capillary electrometer, and in 1887 Waller studied the action currents of the human heart by strapping zinc electrodes, wrapped in chamois and soaked in brine, to the chest and back. He photographed the fluctuations of the mercury meniscus of the electrometer as it responded to the minute electromotive changes in the heart by projecting the image onto a moving photographic plate.

These methods were used by Kreis in 1895 and by Einthoven in 1900 in their pioneer work on electrocardiography Einthoven soon abandoned the capillary electrometer for a modification of the D'Arsonval type of galvanometer which he invented and called the string galvanometer. In this instrument the movements of a fine platinum wire or a silvered quartz thread in a powerful magnetic field indicated the action currents of the heart or other muscle. These movements are also recorded by photography. The projected shadow of the string is allowed to fall at right angles to a slit under which moves the film or paper, and the fluctuations of the string are recorded as a white line. In some of the more recent electrocardiographs the action currents are amplified and then led to a D'Arsonval type of galvanometer. Light is reflected to the moving film from a tiny mirror mounted on the coil

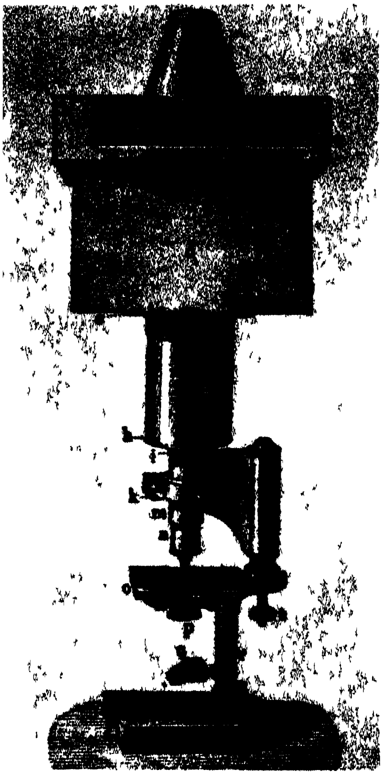

FIG. 2 A MICROSCOPE WITH ATTACHMENT FOR DAGUERREOTYPE PHOTOGRAPHY. THIS IS THE ARRANGEMENT USED BY VON GERLACH IN 1860.

PHOTOMICROGRAPHY

The application of photography to microscopy was one of the first scientific uses of photography This was probably because the microscope had already reached a stage of comparative perfection by the early nineteenth century at the time photography was born, and it was a simple step to combine the two. This was facilitated by the camera lucida attachments of the microscope, which projected an image of the field onto a sheet of paper where it could be traced.

Even before the perfection of the daguerreotype and calotype processes, it

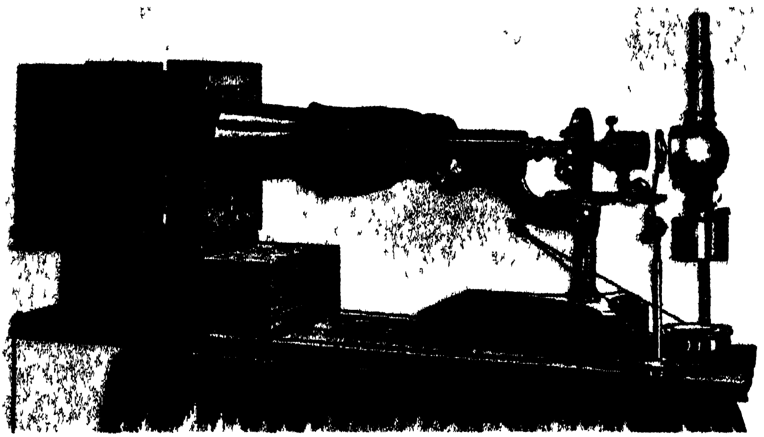

FIG. 3. WALMSEY'S PHOTOMICROGRAPHIC APPARATUS OF 1883
IT IS TYPICAL OF THE TYPE USED DURING THIS PERIOD.

has been reported that Wedgewood and Davy applied their pioneer methods to microscopic photography; and in 1837 J. B. Reade made photographs of entomological specimens and sections of vegetable tissues with a solar microscope. He used paper coated with nitrate of silver and fixed the image with an infusion of galls. However, it was not until Daguerre and Talbot perfected their methods that photomicrography was really successful.

The actual arrangement of the camera and microscope for photomicrography was simple, and has not radically changed even to the present day. Improvements have come mainly through the perfection of photography and to better methods of illumination. The arrangement used by such early workers as Donné in France in 1840 consisted of a box suitably arranged to carry the daguerreotype plate, fitted over the end of the draw tube of a microscope. After the selection and focusing of the field was completed, the eyepiece of the microscope was removed and the image allowed to fall upon the sensitized plate. Illumination was usually by sunlight, although for lower magnifications gas or kerosene lamps were used. Donné in 1840 presented to L'Académie des Sciences a series of photomicrographs made on daguerreotype plates, and in 1845 published with Leon Foucault an atlas which contained engravings taken directly from daguerreotypes he had made Fig. 2 shows one of the daguerreotype cameras arranged for microphotography.

Two problems confronted these early workers: first, the refinement of the photomicrographic apparatus and, second, the development of suitable illumination. Many modifications of the simple camera and microscope were used. Moitessier in 1866 used small plates which were placed over the draw tube of the microscope after removal of the eyepiece. The plates were held in a shallow box arranged with suitable shutters for exposing the plates. This shallow box was held in position over the microscope by a frame, and by means of a sliding arrangement the openings were successively brought into proper relations with the microscope. This arrangement was modified by Verick in 1885. His apparatus consisted of a long shallow box which fitted over the draw tube of the microscope after the removal of the eyepiece. In this shallow box were five movable plate carriers which could be brought successively over the openings of the microscope tube. Another arrangement used by Benecke in 1869 consisted of a rotating disk which carried the plates and brought them successively over the opening of the microscope tube. In all these arrangements a small negative resulted and therefore these methods were particularly useful where weak illumination had to be used. There was also the advantage of convenience and portability, and of course a number of exposures could be made in rapid succession The pictures produced were, however, too small to be of great practicability and better results were obtained with the larger instruments.

The large photomicrographic cameras agreed to a large extent in their general arrangement. The apparatus of Walmsey, Fig. 3, may be considered typical His apparatus, described in 1883, consisted of a bellows camera which was connected to the draw tube of a microscope by·means of a light-proof cloth This prevented the vibration incidental to inserting the plate holder from disturbing the adjustment of the microscope. Light from a kerosene lamp was used for illumination. Excellent work was done during this period by Maddox in England and Cox in the United States, both of whom used arrangements essentially the same as Walmsey's.

At the end of the Civil War work was begun by the United States Medical Museum for the study of "minute anatomical changes characteristic of camp diseases, and of fever and diarrhoea."[3] As a result of this project over 1,400 microscopic slides of both normal and pathological structures were collected, and it was thought desirable to make these findings more widely available. Drawings of these slides were not regarded as ideal, and the far-seeing J. J. Woodward, who was in charge of the medical section of the museum, instituted efforts to reproduce this material photographically. First under Assistant Surgeon E. Curtis and later under J. J Woodward himself, this pioneer work

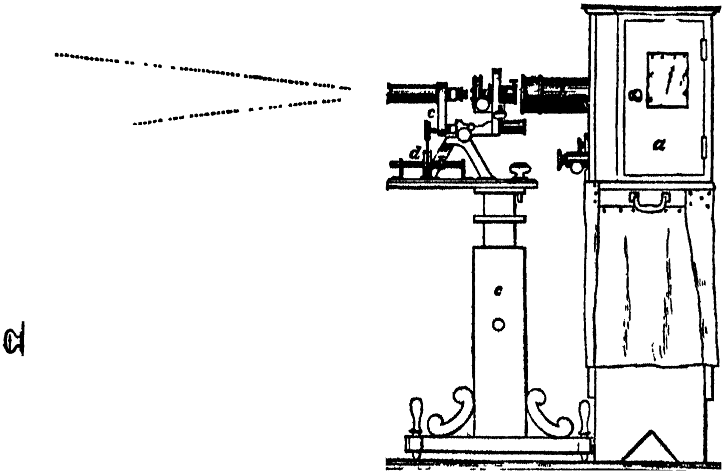

FIG. 4. PHOTOMICROGRAPHIC APPARATUS

USED BY WOODWARD AT THE MUSEUM OF THE SURGEON GENERAL IN 1870. IT WAS USED IN A DARK ROOM. THE ARC OR MAGNESIUM LIGHT WAS CONTAINED IN THE HOUSING "a," AND THE PLATE CARRIED IN THE HOLDER "g."

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[3] This undertaking is described in a rather rare publication of the Museum of the Surgeon-General, "Report on the Extent and Nature of the Materials Available for the Preparation of a Medical and Surgical History of the Rebellion," 1865

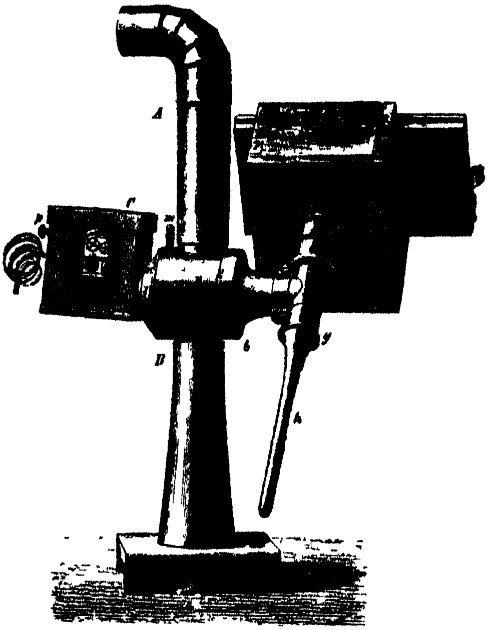

FIG 5. REFLECTING ENDOSCOPE OF DESORMEAUX ADOPTED FOR PHOTOGRAPHY. A PERFORATED MIRROR SET INSIDE THE JUNCTION OF THE TWO TUBES AT "x" REFLECTED LIGHT FROM THE BURNING MAGNESIUM RIBBON INTO THE SOUND "h" THE CAMERA IS AT "F."

was developed. Sunlight was used for illumination and the apparatus was arranged so that the rays of the sun were directed by means of a heliostat onto a condensing lens which focused them on the plane mirror of a microscope. A cell of ammoniacal copper sulfate solution was used to absorb the heat rays. The tube of the microscope was thrust into a long camera box and the connection made light-tight with a black silk cloth. Collodion plates were used and exposures of 30 to 40 seconds were required. With this apparatus, magnifications of 7,000 diameters were attempted, but the greatest success was achieved with the lower powers.

It was hoped that these photographs could be manifolded for general circulation by photo-lithography, but at that time this process proved to be unequal to the task of reproducing the fine textures of the photographic negative, and hand engravings were finally made from the photographs.

In 1870, Woodward, dispensing with the camera as such and using a totally dark room, began experiments with artificial light. The light source, consisting either of an arc light or a magnesium light, was enclosed in a light-tight box, and the rays were allowed to fall upon the achromatic condenser of a microscope after they had passed through an ammoniacal copper sulfate solution and a condensing lens This arrangement is shown in Fig. 4, which is taken from Woodward's original report to the surgeon general.[4] The microscope was focused with the aid of the eyepiece, which was then removed, allowing the image to fall on the plate. The plate was fastened to a support which could be moved about the room by means of castors. The pictures made with this arrangement were 5 inches in diameter and are still beautifully clear and sharp.

The artificial light employed by Woodward was somewhat of an innovation. The illumination previously employed was either sunlight for high magnification or the light of the gas or kerosene lamp for lower magnifications. C. F. Grehore of Boston had made some use of an arc light, as had Moitessier with his small camera, and the oxy-calcium light had been used by Dr. Wilson in 1867. Using the arrangement shown in Fig. 4, Woodward experimented with both of these light sources with excellent results. He lays claim to originality in the use of this kind of illumination in the following words: "I have no hesitation, therefore, in claiming for the Museum and for myself the credit of having demonstrated the serviceable character of these lights as sources of illumination for the preparation of negatives with high powers, and of having devised a simple method which brings their use within the reach of every microscopist."

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[4] "Report to the Surgeon-General of the United States Army on the Magnesium and Electric Lights as Applied to Photo-micrography," by J. J. Woodward, 1870.

Among the ingenious auxiliary devices for photomicrography was the means of taking stereoscopic photomicrographs. This could, of course, be done by photographing the images in the two tubes of a binocular microscope, but the same result could be obtained, as explained by Benecke, by slightly tilting the slide so that two photographs could be taken at slightly different angles. He used a tilting table which was attached to the stage of a microscope and he controlled the amount of inclination by the use of a wedge so that a matched pair of photographs would result This was applied most successfully to opaque objects. Another device used in 1866 by Moitessier consisted of a cap which fitted over the objective of the microscope This cap turned through an angle of 180 degrees and obscured opposite sides of the objective successively Photomicrographs thus taken gave a stereoscopic effect when properly viewed.

The inherent lack of depth of focus in the microscope was at least partially overcome by Villanes, who made successive exposures of different planes of focus. He provided the knob of the micrometer adjustment of the microscope with an index pointer and circular scale. After noting the position of the pointer when the lowest and highest part of the object was in focus he made three or four exposures on the same plate, changing the index pointer to different positions on the scale between the two extremes of focus previously noted. The resulting negative is not as clear as one made with a single exposure, and this procedure has not enjoyed very extensive use. The problem of the small depth of focus in microscopic photography is inherent in the lens system of the microscope, and the most practical plan has been to focus on the most important part of the field.

By 1890, amateur photography had become wide-spread, and with the ubiquity of amateurs no field of photography was left unexplored. This enthusiasm is evidenced by the fact that in the *American Annual of Photography* for 1891 there are three articles dealing with photomicrography. Although much of the work done by these amateurs must have been as a hobby rather than a science, it must be admitted that they simplified photomicrography to its barest essentials. One of these articles describes an arrangement by which a box camera without any alteration whatsoever may be used for photomicrography by bringing its lens almost into contact with the eyepiece of a microscope. The two are joined by a metal ring, and with a kerosene lamp for illumination excellent photographs were taken with an exposure of 3½ to 10 minutes. Quite recently this arrangement was reported as something new

In recent years there has been a revival of interest in photography with a microscope among amateurs. This has been due, in part, to new developments of photographic materials and the use of color filters with panchromatic emulsions. But another factor of probably

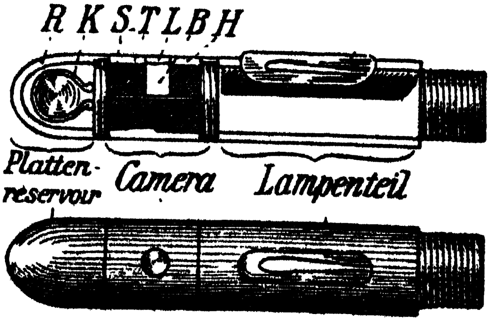

FIG. 6. GASTRIC CAMERA

DEVISED BY LANGE AND MELTZING IN 1898. IT WAS CARRIED INTO THE STOMACH ATTACHED TO A STOMACH TUBE. THE ROLL OF FILM IN THE CAVITY "K" WAS DRAWN PAST THE LENS "L" BY MEANS OF A CORD EXTENDING THROUGH THE STOMACH TUBE. AN ELECTRIC LIGHT "G" EXPOSED THE FILM.

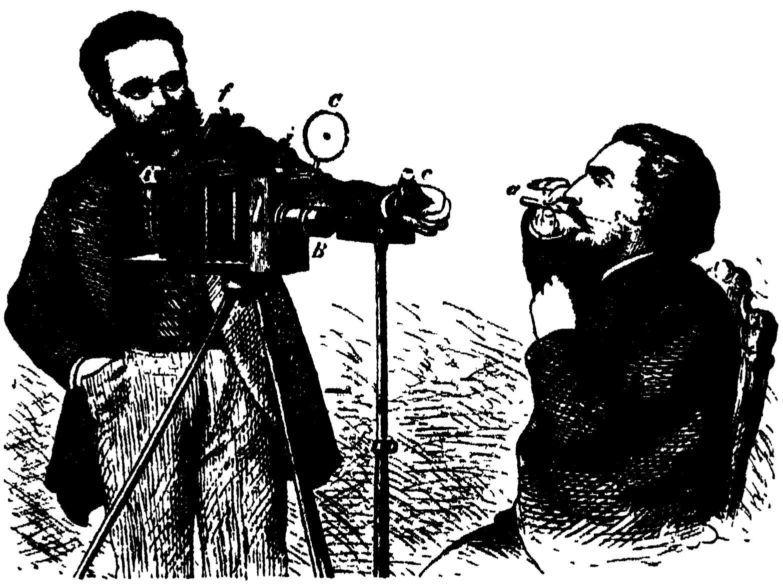

FIG. 7. EARLY METHOD OF PHOTOGRAPHING THE LARYNX.

THE SUBJECT MANIPULATED THE LARYNGOLOGICAL MIRROR, OBSERVING ITS MOVEMENTS IN THE MIRROR "c." LIGHT FOR ILLUMINATION WAS FURNISHED BY THE PERFORATED MIRROR "C."

greater importance has been the interest of the modern artist in design. The artistic photographer has found that the microscopic world abounds in rich patterns and he has turned his camera to this new field for artistic inspiration.

PHOTOGRAPHIC ENDOSCOPY

Endoscopy, or the visual inspection of hollow organs, was first accomplished by the insertion of a suitable metal tube into the organ. Examination was made with the aid of light reflected through this tube by a mirror perforated for observation. Desormeaux, though not the first to make use of this principle, thoroughly studied the possibilities of such an arrangement for the visualization of the interior of the bladder. He began his experiments in 1852 and in 1855 had perfected his methods. A description of this instrument and the results of ten years' experience with it were published in 1865.

Desormeaux's endoscope consisted essentially of a sound which was suited to the organ to be examined, and of a mirror set obliquely at the outer opening. A beam of light was reflected by the mirror, passed through the tube and illuminated the structures within. Light from the burning of a mixture of alcohol and turpentine was used for illumination. It required but small modifications of this instrument to adopt it for photographic purposes. Fig. 5 shows Desormeaux's endoscope combined with a photographic camera[5] With proper sounds this apparatus could be used to make photographs of the urethra, bladder and rectum. A modification depending upon the same general principle of observing or photographing the field through a perforated mirror was used by Brunton, who developed an otoscope, which was easily adapted for photography by the addition of a suitable camera.

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[5] This figure is reproduced from "Das Licht im Dienste Wissenschaftlicher Forschung," by Sigmund Stein, published in 1885. Stein was very active himself in applying photography to the sciences and his book describes in a great detail the photography of his day in the service of science and contains many illustrations. Figs. 1, 2, 5, 7, 10 and 12 are from this book.

Attempts were made to photograph the stomach by similar methods without success. Photographic gastroscopy was too great a problem for reflected light, and indeed even when illumination of the stomach cavity by means of an electric light carried into the stomach with the stomach tube made visual gastroscopy comparatively simple, practical photography was still extremely difficult Visual gastroscopy was attempted with some success by Kussmaul in 1868, and Trouve in 1873, but it was not until Mickulicz in 1881 used a small electric bulb on the end of the gastroscope to illuminate the stomach that observation became really possible, and even then it was attended with practical difficulties. Photography of the image seen in the gastroscope was successfully achieved by Elsner, who in 1928 was able to photograph the image observed with the gastroscope, but the procedure was too complicated to be practical.

Successful photography of the interior of the stomach was finally accomplished, however, by the innovation of introducing the camera itself into the stomach. This arrangement seems to have been first used in 1898 by Lange and Meltzing, who took advantage of the then comparatively new flexible film. A small strip of this film a little more than 4 mm in width was rolled into a loose spiral and placed in the end of the apparatus in the small cavity at K in Fig. 6, which is a reproduction of an illustration from the article by these investigators. This film strip was drawn past the lens L through the slot S by means of a strong cord, which extended through the lumen of the tube to the outside. By pulling this cord a short distance after each exposure, successive negative images could be secured on the film strip. The exposure was made by turning on the light for one half to one second. A circular negative 4 mm in diameter was secured. This ingenious device was, however, limited in its success. The difficulty of orienting the camera made it too much like "shooting in the dark" for practical use

This development was the forerunner of the gastrophotor, invented by Heilpern and Porges in 1930, in which 8 stereoscopic photographs covering the entire interior of the stomach are taken by means of pinhole cameras which eliminated the necessity of focusing. After uncovering the pinholes a single flash of intense light lasting for 1/120th of a second exposes the pictures All portions of the stomach are photographed simultaneously, and the exact conditions of the interior of this organ can be determined. Although it lacks the advantage of showing natural colors, there is no doubt but that this recent achievement of photography will prove of the greatest diagnostic value.

Photography of the Larynx

Early attempts to photograph the larynx were made by Johann Czermak in 1860. He had improved and extensively used the laryngoscopical mirror which had been devised by Robert Liston and Garcia in about 1854. His photographic methods consisted essentially of photographing the image in the laryngological mirror. The subject manipulated the laryngological mirror observing its reflections of the larynx by means of a small plane mirror. Light was thrown into the pharynx by a concave mirror with a central opening similar to the present-day head mirror. An observer, by applying his eye to the opening in this mirror, could observe approximately the same image in the laryngeal mirror as the subject. Photography was accomplished by placing a camera behind the perforation of the head mirror in the same position as the eye. The kerosene lamp, which was not sufficiently bright for photography, was replaced by sunlight. By this means Czermak was able to make fairly good photographs of the normal larynx. He was handicapped by the comparatively primitive state of photography, and of course, since autolaryngological methods were used, the application was distinctly limited. Minor improvements on the general method used by Czermak were made by Stein, whose arrangement is seen in Fig. 7, and the same methods were used by others, but without marked improvement over the results obtained by Czermak

In 1884 Lenox Browne and Emil Bhenke used photographs to illustrate their book, "Voice, Song and Speech." They attached a mirror to the shutter of the camera and the subject watched his manipulation of the laryngeal mirror in this mirror. Upon his signal the operator tripped the shutter, and the exact image which he observed impinged itself upon the sensitive plate. By this simple arrangement, the parallax which was present in other methods was avoided. Light from a 10,000 candle power arc-light was used for illumination. This passed through a water chamber to reduce the heat, through two plano-convex lenses and was reflected by a plane mirror into the pharynx A rapid rectilinear lens was used and an exposure of one fourth second was required.

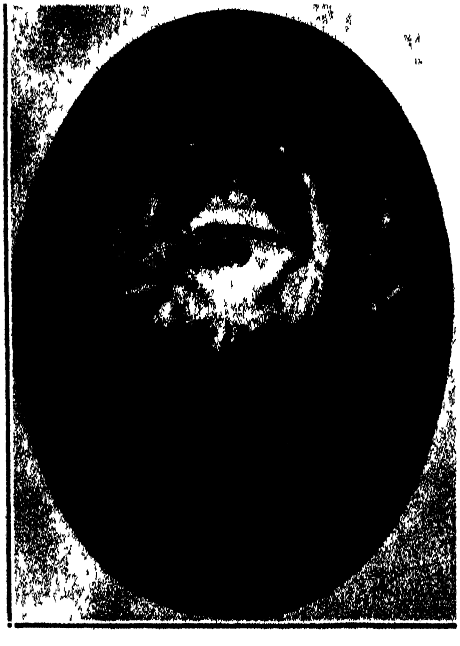

FIG. 8. A PHOTOGRAPH OF THE LARYNX

TAKEN IN 1884. THE LARYNX IS SEEN REFLECTED BY THE LARYNGEAL MIRROR IN THE CENTER OF THE PICTURE.

One of the photographs taken in this manner appeared as the frontispiece of "Voice, Song and Speech" and is reproduced in Fig. 8. The actual image of the larynx is very small and the major portion of the plate is taken up with the out-of-focus image of the subject. In this photograph one can see how the picture was taken. The right hand is seen holding the mirror, and the forefinger of the left hand, which has just been lowered as a signal to trip the shutter, can just be made out. The small portion of the plate containing the image of the larynx was enlarged by copying for detailed study. Photographs reproduced in the book were used to show the position of the vocal cords during the production of different notes in singing.

These methods, while they reproduced the larynx, were subject to serious disadvantages. They could be used only by a subject who had skill enough to demonstrate his own larynx, and were thus restricted in their use to scientists or investigators, and could not be used with ordinary patients.

In 1882 Dr. T. R. French and Mr. G. B. Brainerd devised a method of taking pictures of the larynx which was both new and unique, and entirely supplanted the methods using the conventional camera. Dr. French was clinical professor of diseases of the throat and nose at the Long Island Hospital of Brooklyn. There he treated Mr. Brainerd, a civil engineer and amateur photographer, for a minor throat condition. Because of this situation, Mr. Brainerd became interested in the problem of photographing the larynx and cooperated with Dr. French on the mechanical and photographic part of the problem. After a few experiments using the conventional type of camera, they discarded it in favor of a small hand camera which in appearance resembled some of the miniature cameras which are so popular today They worked two years perfecting their apparatus and procedures and finally were able to take photographs wherever visual examination of the larynx could be made with the laryngeal mirror. In its perfected form the camera was 10½ by 1½ by ⅞ inches, with an achromatic meniscus lens ½ inch in diameter with a focal length of 1⅝ inches, and was held in a tube in front of the camera. The shutter was of hard rubber and dropped by gravity across the field when the release, located conveniently in front of the camera, was tripped. To one side of the camera an arm carrying a slightly convex laryngeal mirror was firmly attached The mirror was thus kept in rigid relation with the lens and plate of the camera. An arrangement was made whereby five pictures could be exposed with one loading of the camera.

The arrangement for using this instrument is seen in Fig 9, which is a reproduction of cut in one of the original articles by Dr. French. Sunlight used for the illumination passed through a system of condensing lenses and was reflected by a head mirror into the pharynx. The laryngeal mirror attached to the camera was manipulated by moving the entire camera, which was held in the operator's right hand while he observed the image through the opening in the head mirror. At the proper moment the shutter was tripped and the image secured on the plate was almost the same as that seen by the eye. The small amount of parallax could be compensated for after some experience. With this apparatus and with the "instantaneous exposures" of which it was capable, studies were made of the normal larynx during phonation and of the larynx in numerous pathological conditions. Without a doubt, this apparatus was the first method by which the larynx could be photographed in such a way as to yield results from which scientific studies could be made.

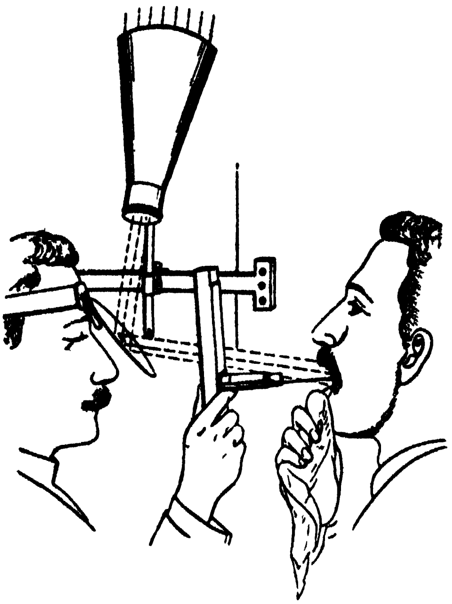

FIG. 9. PHOTOGRAPHY OF THE LARYNX

BY MEANS OF A SMALL HAND CAMERA DEVELOPED BY FRENCH AND BRAINERD IN 1882. SUNLIGHT, AFTER PASSING THROUGH THE CONDENSING LENSES, WAS REFLECTED INTO THE PHARYNX BY THE HEAD MIRROR.

Once it had been pointed out that large plates were unnecessary and that the usual bulky camera was a handicap, rapid strides were made. Sigmund Stein adapted to the photographic purposes the illuminated laryngoscopical mirror developed by Nitze and Leiter and patented in 1878. This mirror carried a small electric bulb cooled by a suitable water system at the apex of the laryngological mirror. This was combined with a small camera essentially

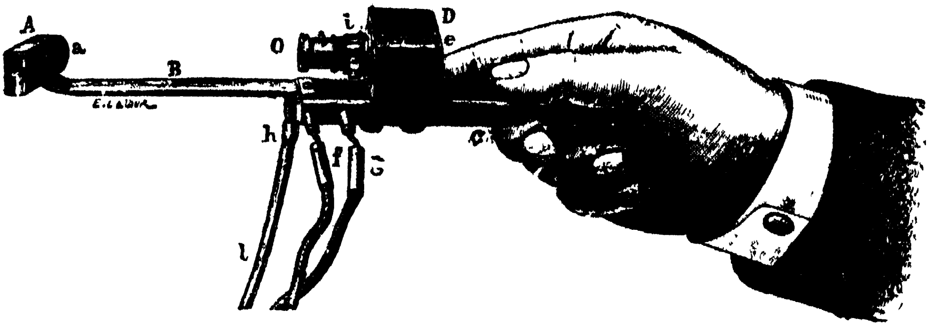

FIG. 10. LARYNGEAL CAMERA.
STEIN'S IMPROVEMENT OF FRENCH AND BRAINERD'S CAMERA AN ELECTRIC BULB COOLED BY CIRCULATING WATER FURNISHED ILLUMINATION

similar to that of French and Brainerd, except that an electrically operated shutter was used. The small electric bulb held close to the larynx was more efficient than the sunlight and made the investigator independent of the weather. Stein's camera is shown in Fig. 10

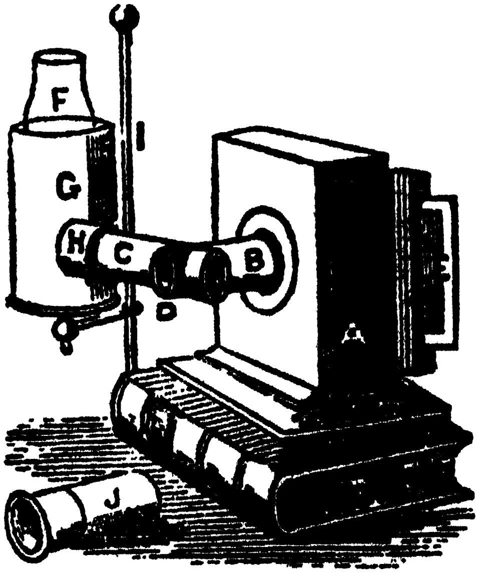

FIG. 11. ROSEBURGH'S APPARATUS
FOR PHOTOGRAPHING THE FUNDUS OCULI OF THE EYE IN 1864. THE EYE WAS PLACED AT "D," LIGHT FROM THE LAMP "G" WAS REFLECTED INTO THE EYE BY A GLASS PLATE SET IN THE JUNCTURE OF THE TWO TUBES. A LENS WAS PLACED IN THE TUBE "B" AND THE PLATE-HOLDER IS AT "E."

Thus photography of the larynx became practical, and the most recent improvement has been an instrument devised by Otto Ehrentheil and Franz Black, in 1932, in which a tiny pinhole camera with an electric light is carried back into the pharynx to make a direct photograph of the larynx.

PHOTOGRAPHY OF THE FUNDUS OCULI

As early as 1862 attempts to photograph the retina were made by Noyes of New York. He was unsuccessful, however, and his negatives only imperfectly represented the retina. He described his methods before the Section d'Ophthalmologie du Congres Copenhague in 1864. Sinclair of Toronto, Canada, also made some attempts, but both of these investigators encountered great difficulty, due to reflections from the cornea and the movements of the eyeball during the long time required for exposure.

The first successful photography of the fundus oculi was accomplished by Roseburgh in 1864. A reproduction of an illustration of his camera which appears in his original report is shown in Fig. 11. A plate of glass set at the junction of the two tubes served to reflect the light from an external source into the eye and also allowed the image of the retina to pass to the sensitive plate. The wet collodion process was used, and an exposure for five seconds was required when bright sunlight was used for illumination. With such brilliant light it was found impossible to photograph the human eye, but by using cats which were anesthetized with chloroform and whose pupils had been dilated with atropine, he secured photographs of the fundus oculi. This apparatus could also be used as an ophthalmoscope if a kerosene lamp was used for illumination, and a ground glass replaced the photographic plate. Roseburgh mentions troublesome reflections from the cornea and surfaces of the lenses, which interfered greatly both in photographing the eyes of cats and in examining the human eye. These reflexes or "flares" have proven most troublesome in all attempts at fundus photography, and many of the subsequent efforts of investigators were directed toward the problem of their elimination.

The apparatus of Roseburgh was modified in 1880, by Liebreich, who used a perforated mirror instead of a plane glass to reflect light through the pupil. The perforated mirror for the examination of the fundus was devised by Helmholtz in 1852, and was subsequently used extensively by the pioneer ophthalmologist Albrecht von Graefe It was a simple matter to combine this with the camera for photography. Liebreich's apparatus is shown in Fig 12 A metal concave mirror 11 mm in diameter with a perforation located at its center, reflected light through the pupil and onto the retina, while a lens located immediately behind the perforation in the mirror projected the image to a photographic plate. The pupil was dilated with atropine, and an arc light magnesium light or the sun was used for illumination. The eye was in some measure protected from this brilliant illumination by a blue-violet glass or a cell containing a solution of ammoniacal copper oxide, located in the tube between the mirror and the eye. Exposures of ¼ to 2 seconds were required, and a picture 1 to 3 cm in diameter was produced, depending on the lens system used.

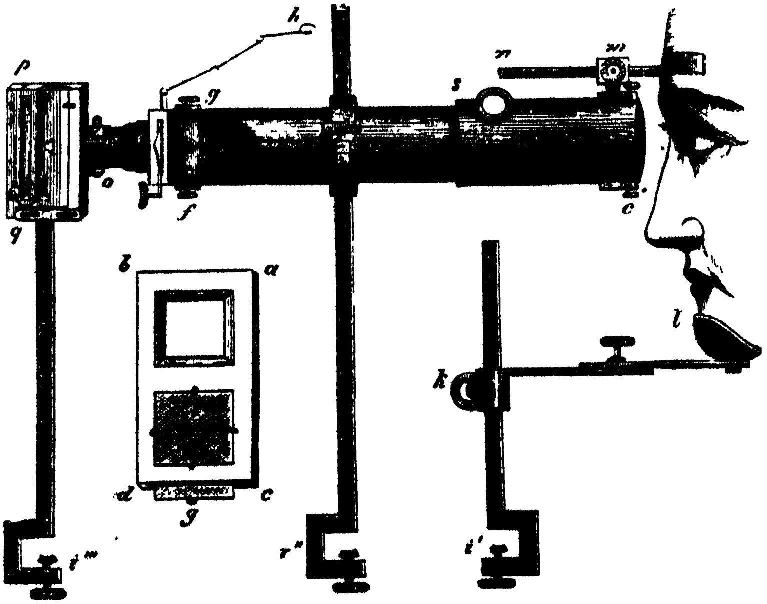

FIG. 12. PHOTOGRAPHIC OPHTHALMOSCOPE

USED IN 1880 BY LIEBREICH. A PERFORATED MIRROR AT "R" REFLECTED LIGHT INTO THE EYE. THE CAMERA IS AT "PQ" WITH ITS LENS AT "O."

Flares or reflexes were not the only obstacles encountered in photographing the fundus oculi. The reddish hue of the retina necessitated extremely long exposures with the red-blind emulsions. To overcome this, Barr in 1887 used plates which he bathed in a solution of erythrosin, silver chloride and ammonium hydroxide to increase their sensitivity to the red color. This was a material aid, but the problem of illumination was still a difficult one. The retina is too sensitive to be subjected to excessive illumination, and yet an unusually large amount of light is required for photographic purposes.

This problem appears to have been solved by the use of a brilliant flash of light furnishing an intense illumination for a short period during which the film or plate is exposed. Guilloz in 1893 focused the camera and arranged his mirrors and lenses by means of a gas lamp, the light of which did not injure the eyes. After proper adjustments had been made a magnesium mixture was pushed into the flame giving a flash for the exposure. A similar arrangement was used in 1902 by Thorner, who aligned the flash and adjusting lamp so that after the image was focused properly the flash illuminated the same field as the lamp. Friedrich Dimmer, in the same year, used a brilliant arc, the light of which was obstructed by means of an opaque glass and when the shutter was tripped the glass was momentarily drawn aside

In the illumination of the retina Thorner and Dimmer attempted to eliminate flares, by projecting a beam of light through only a portion of the pupil, leaving the central part for photographic purposes. This principle, as it was finally developed in the Nordensen camera of the present time, has made it possible to eliminate these flares almost entirely and, as a result, the photography of the fundus oculi has reached its perfection. With the Nordensen camera many beautiful studies of the fundus oculi have been made—studies which even surpass drawings and sketches in their value for teaching and record.

THE EMERGENCE OF THE CICADA

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AFTER spending almost seventeen years underground, undergoing various stages of development, the emergence of the cicada (*Cicada septemdecim* or so-called seventeen-year locust) from its yellowish-brown semitransparent shell is

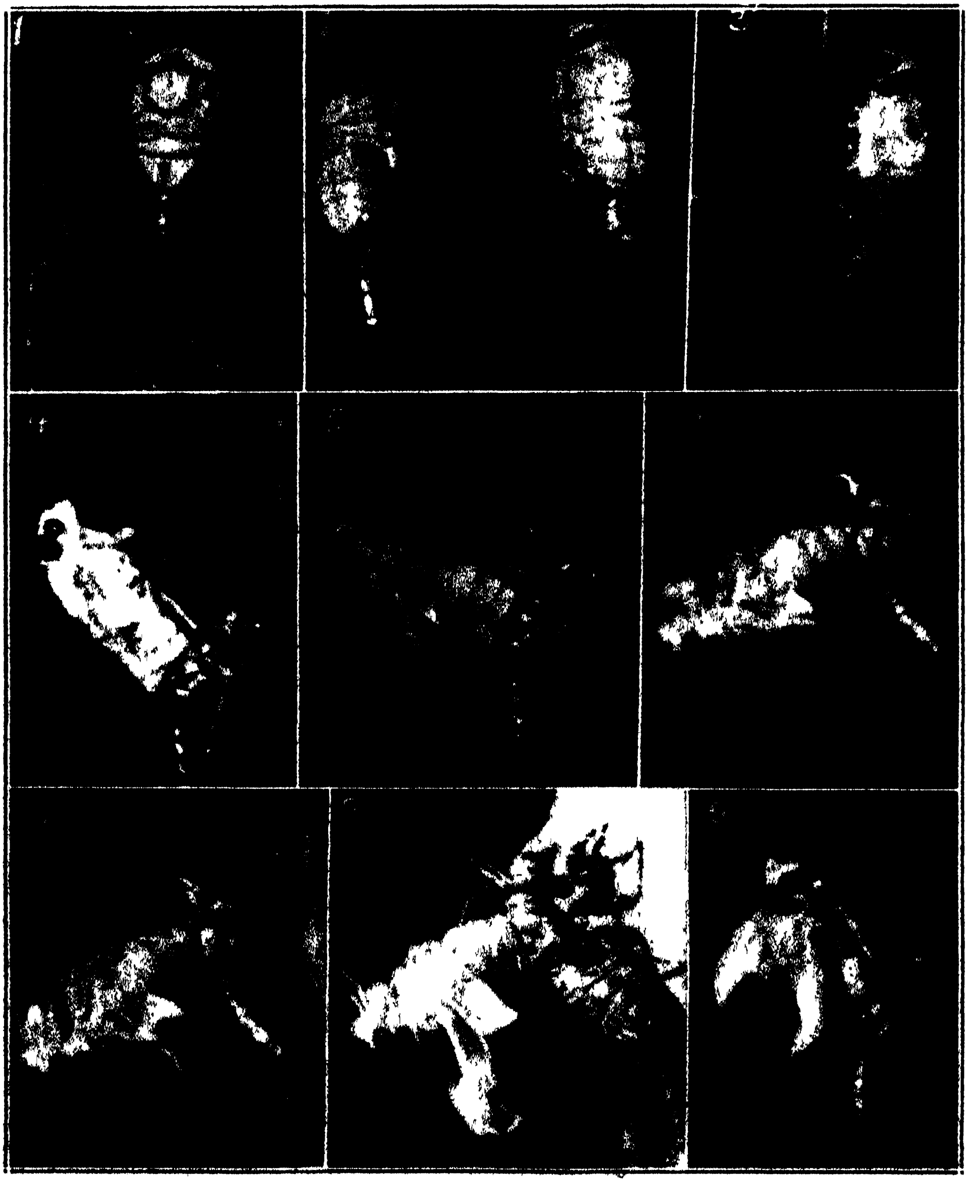

PLATE 1.

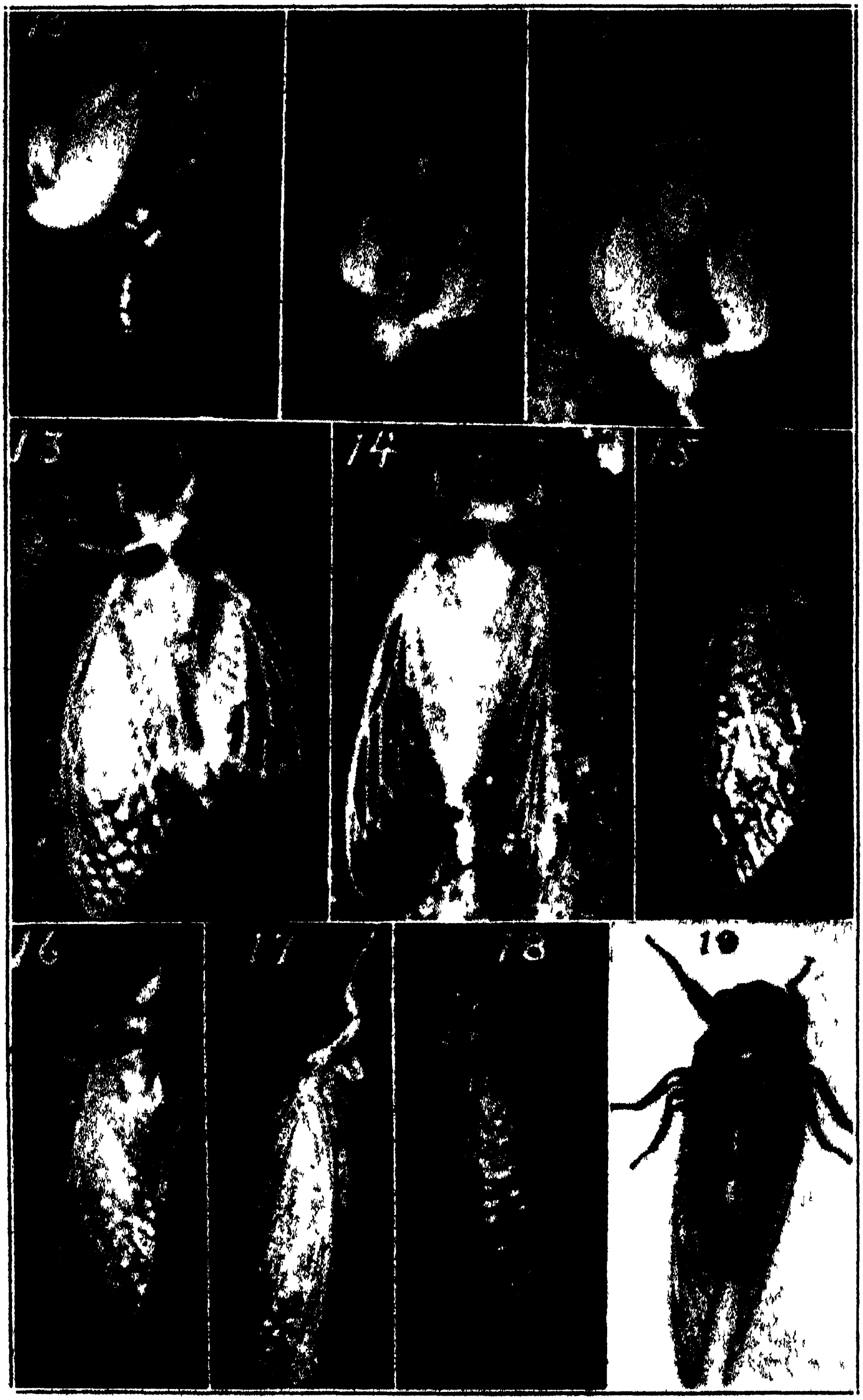

PLATE 2.

an occurrence that enthralls all who have an opportunity to watch the event.

Having plenty of specimens available in my back yard, and finding so many persons, young and old, interested, once their attention was called to this phenomenon, it was instructive to secure a photographic record of this transition.

Although the emergence of the adult from the shell is a fairly continuous and orderly process, there are several distinct phases that are worthy of description.

First let us consider the exit from the ground. This occurs under trees (beeches, oaks, etc.) or places where there had been trees, the young, succulent branches of which had served as a depository for the eggs seventeen years earlier.

Having spent all this time underground, undergoing the usual morphosis from larva to pupa, we found immature specimens of the latter while setting out bushes some three years ago, and again early in March and April of this year. Early in May some of the more hardy ones dug holes to the surface and waited for a warm evening to come out of their subterranean abode. It was interesting to watch them just beneath the surface, and, if disturbed, see them drop down about two inches underground, where they rested, secure from birds.

The exit from underground occurred at sundown, or even earlier in the shaded part of a woods. The dry leaves fairly crackled as a dozen or more crawled toward the host tree, which some mounted to a height of ten to thirty feet. Late-comers settled on the trunk or mounted small bushes—anything that provided a good toe-hold, which is an important item in the emergence from the hard shell.

The propitious time for bursting and emerging from the chitinous casing having arrived, the ceremony preceding the event consists in rubbing the thick femora of the fore-legs over each other, then stroking the antennae with the fore-legs and sometimes stroking the sides of the abdomen with the hind legs.

Apparently this ritual is for the purpose of limbering up and facilitating the withdrawal of these organs from their hard casing — an important detail, judged by the high mortality as indicated by the number of insects that succeeded in bursting the outer casing, but failed to withdraw the head and died in armor.

On completion of the massaging ceremony the insect proceeds very deliberately to sink its sharp-hooked claws into the underside of a leaf or the side of a tree upon which it is resting—but always in such a position that, after partial emergence, the body hangs with the head away from the shell, back downward, so that the wings can expand freely—presumably assisted by the action of gravity (see Fig. 8).

How does the insect burst its shell? That is an interesting event. Firmly attached to the leaf or bark by means of the sharp claws of its six feet, it proceeds to draw the terminal part of the abdomen toward the central part of the casing. This is a step-by-step, wave-like process, as the segments of the casing expand, radially, in succession, from the tip of the center of the body. This puts great pressure in the region of the thorax, which bursts the casing at this point (see Fig. 1). The round appearance of the casing, after emergence of the insect, as differing from the flat abdomen before fracture of the shell, is well illustrated in Fig. 2. In one instance the insect worked perhaps fifteen minutes and, not succeeding in breaking the shell, suddenly walked off, leaving me to find another specimen to photograph.

Once the casing is broken the first stage of the emergence proceeds rapidly. In the course of a few minutes the part of the thorax containing the two conspicuous black spots appears. Then the beautiful light-colored, orange-red eyes appear (Fig. 2). Notice the unfolded wing extending under the translucent sheath.

After further pulling (action shown in Fig. 2) the front legs are withdrawn (Fig. 3) and the insect swings back, as shown in Fig. 4. In this position some half a dozen filaments ("guy ropes") attached to the sides and beneath the thorax are visible. After some kicking the hind legs are free (Fig. 5).

In the course of five to ten minutes after swinging freely (Fig. 5) back downward, the small orange-yellow masses (wings) at the sides partially unfold (Fig. 6), and movements are visible as the wings continue to expand (Figs. 7 and 8).

After the wings have partly unfolded the insect raises itself upward and forward (Fig. 9) over its shell, which it grips with its front feet, and proceeds to pull the rear end of its body out of the casing. This is a very active period, and sometimes it involves quite a struggle to release the abdomen. In Fig. 10 the insect is shown pulling with its fore-feet, trying to free its abdomen from the shell. By gently tapping its head with the finger I succeeded in inducing the insect to remain quiet long enough (one second) to secure a fairly clear picture.

Once released, the insect clings to its shell with its two sharp-clawed front feet, and swings its body free from its former armor. This allows its wings to expand. The various stages are shown in Figs. 11 to 13.

In this stage the wings have a faint bluish-white glow, under a flashlight, and the outer vein is a light yellowish tint. In the early stages, the diaphanous membranes of the wings, between the veins, are bulged upward, giving the peculiar spottedness in the photograph (Fig. 13). As the veins expand and harden, these membranes become more taut. As the outer vein becomes hardened the wing folds closer to the body (Figs. 14, 15, 16).

The rest of the body is, of course, white, except the two black spots on the thorax, which are conspicuous from the very beginning of emergence (Fig. 2). On first emergence the rest of the thorax appears a silky, faint-pinkish, white (Figs. 1 to 3).

The complete emergence requires about thirty to forty minutes. In the course of the next hour or two the body of the insect grows darker and darker, and by the following morning it is entirely black (Figs. 16 to 19).

If the English sparrows, gray squirrels, crows, etc., do not get him, he is then ready to fly to the highest tree-top, where, by raising the tip of his abdomen, he emits his famous "A-a-a-a-a-o" note, which he repeats three to five times, and then pauses for a short rest. The last part of the note is much fainter and occurs when he drops his abdomen—apparently his vibrator is not properly damped.

Only the male sings. The female is unable, and hasn't the time to sing. She is busy with her lance-tipped ovipositor puncturing this year's growth of succulent tips of trees and depositing several hundred tiny white eggs, which in the course of a few weeks hatch into larvae that drop to the ground, to begin a new cycle of sixteen years of burrowing beneath the surface, feeding upon the root-juices of vegetation; then, after a brief existence as pupae, emerge from the ground in 1953. In the meantime, owing to the lack of sunshine, let us hope the mortality from rickets is not too great. Certainly they are not a good advertisement for the advocates of vitamin D, irradiated food, etc.

Just why this interesting insect is doomed to a life of digging underground for almost seventeen years is an interesting question. Most other insects complete their cycle from egg to larva, pupa and maturity in from a few months to a year. Even his cousin the lyreman (*cicada tibicen*) appears biennially, with a different brood maturing yearly to enliven the hot August days with his shrill notes.

But if nature has doomed him to digging for 16 plus years, it has provided him with suitable tools in the form of a pair of thick-clawed, fossorial anterior

Hatching from a spindle-shaped egg, about 2.5 mm. long and about one tenth that size in diameter, the most conspicuous part of the larva is the long antennae, the pin-point sized dark eyes (why eyes if he must work underground?) and the heavy-femured fore-legs, ready for digging. Excepting for the lack of wing pads and the presence of unusually long antennae, the freshly emerged larva is not unlike the encased insect shown in the photographs.

In spite of its extremely fragile appearance, the newly hatched insect, if given the opportunity, at once proceeds to dig in, and in a few minutes has disappeared underground. This is a story in itself to those interested in the subject.

From sticks containing eggs, picked up under trees, the writer has had pleasure in watching the process of development of the egg from an undifferentiated white spindle to the stage when it became tipped with two dark specks (the eyes). The spindle then began to vibrate, to and fro; and the larva broke open the casing and emerged. From these dry branches over 600 larvae were hatched, controverting the popular belief that the sap in the tree is a necessity to development of the egg.

My first experience with the cicada was as a boy of nine; they were "locusts" and I was not allowed to go barefooted "because they would sting." I was told also that they sang "Pharaoh" and the "W" on the wing meant "war." Well, we have had plenty of war, within and outside the locust season. The "W," "M" or more likely "N" is visible near the tip of the wing (in Fig. 19).

THE TRENDS IN MODERN GENETICS

AN EVALUATION OF CURRENT RESEARCHES

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GENETICS is that branch of science which investigates the origin, the development and the heredity of traits or qualities which, in the aggregate, constitute the inborn endowments of living organisms—plants, animals and men. Genetics involves also the study of the mechanism, the chemistry and the physiology of reproduction, and finally it concerns studies on the origin and evolution of species, and on those forces—both internal and external—which effect the rise and fall of racial stocks.

A generation has passed since genetics established itself as a definite scientific discipline. The foundation story can now be told from a historical point of view.

Since the basic purpose of genetical research is to seek the truth about the inheritance of definite qualities in plants, animals and man, using all methods and tools available, the questions arise: What are the main problems which now call for definite research in this science? Among these problems, what is their relative value in terms of chance of profitable discovery about genetical principles or in filling gaps in existing knowledge? In view of the present status of the science of genetics as a whole and of the facilities and resources available, to what relative emphasis is each line of current genetical research entitled? The specific purpose of the present paper is to make such a short but critical review and to take stock of its lessons.

As an art genetics is very old. As a modern science it is new and still finding itself. As a pure science genetics grew out of more definitely controlled and better understood experiments in breeding. These experiments had for their main purpose the improvement of domestic varieties of plants and animals for man's use. The great impetus to research in many phases of organic evolution which science received a generation ago was due to the fortunate interaction of a number of things: First, there must be listed the general appreciation of the principle of evolution as a general rule in the organic world; second, the practical increase in numbers, specialization and blood-purity of varieties of domestic plants and animals, and the better understanding of both the basic principles and the practical rules by which husbandmen accomplished breed-improvement of their domestic stocks; third, the rediscovery of Mendelian principles in 1900; fourth, the general advance in analytical methods and laboratory technique in biological study, particularly the advance in cytology, embryology, biochemistry, physiology and psychology; and fifth, the more critical application of mathematical analysis to research in biology, including the demand for more accurate and quantitative measures, that is, for better yardsticks for the specific qualities under genetical investigation. All these factors interacted to advance rapidly the effective organization of the science of genetics, as the more critical study of the origin, the development and the heredity of the constitutional or inborn qualities in plants, animals and man had come to be known.

Judged from past history and present status, in the following paragraphs we shall list briefly the principal subjects of genetical study, list the trends of research, attempt briefly to evaluate the contributions of each line of study and to indicate the most profitable lines of genetical research for the immediate future.

(1) HEREDITY AND ENVIRONMENT

Heredity and environment have, for many generations, been the subjects of long and warm debate. These debates have argued both pro and con: Which is more important, or which plays the greater rôle in the individual's status—heredity or environment? Or, to be more specific: In a given case just what part has heredity played and just what part has environment played in producing the particular end-result, the qualities but not the causes of which no one doubts?

The truth seems that in every individual plant or animal at every stage in the individual's development, from the single cell to death from old age, such individual status is the resultant of the interaction of heredity and environment. These relative influences are rarely the same. In some qualities heredity seems to have been the controlling influence and in others environment. But the basic substances, structures and qualities on which environment must work are furnished by heredity. Whether the particular egg will develop into a mouse or a rat depends upon heredity; if a mouse, whether white or gray, again depends upon heredity; and if a white mouse, whether specially susceptible or resistant to some diseases, such as rickets, depends about 50–50 on heredity and environment. Hereditary resistance or susceptibility, which latter is resistance at the negative end of the scale, seems to be, in this case, acted upon by nutrition differentially among different family stocks.

An essential part of the clear statement of every problem in genetics consists in provision for the relative evaluation of heredity and environment before the more specific genetic problems are attacked. Science still needs many more specific data before it can generalize more satisfactorily on the heredity-environment problem.

(2) THE MECHANISM OF HEREDITY

The special phenomena of heredity were found to parallel closely the special cytological phenomena found in the duplication, reduction, segregation and recombination of chromosomes and parts of chromosomes in the preparation of the egg and the sperm for union in bi-sexual heredity. This mechanism managed beautifully to prevent the piling up of chromosomes in bi-sexual heredity. The Mendelian rules, based upon the somatic ratios in the offspring, thus squared with both the distribution-ratios of the same definite somatic qualities among their ancestors and with the chromosomal mechanism seen by the cytologist. These principles involve the concept of segregable units of heredity quite comparable, indeed, with the atom-concept in chemistry—the principle of segregation and recombination. In certain cases and in some forms of plants and animals the rule worked to perfection, so that with the parallel development of definite knowledge about the mechanism of chromosomal duplication, segregation and recombination in the germ cells, a mechanism was found which explained the basic phenomena of heredity.

Experimentation followed with many traits and qualities in many species and varieties of plants and animals and in many races and family-stocks of man—all seeking the needed "atom"—the unit of heredity. Thus the mechanism of heredity seen by the cytologist and the mathematical ratios of actual traits seen by the breeder in the Mendelian laboratories tied up so well that at one time the whole problem seemed solved. Much basic truth had been found, but the final generality which the beautiful tie-up promised was too simple and definite to tell the whole story. The main difficulty seemed to be that, while the unit-concept in heredity served a great use as did the "uncutable atom" in chemistry, it was so fixed a concept that it tended also to obstruct progress along other lines.

(3) MUTATION

As a general rule experimentalists have not yet been able to show whether or when a mutation, which is a definite hereditary change in the species, is due to a chemical change in the nature of the gene or a portion of the chromosome, to a positional shift of chromosomes or parts thereof, or simply to different chromosomal combinations in egg and sperm, causing repeatedly a new but constant outcome in somatic development.

Thus the genetics of segregable units of heredity is not the whole of genetics, promising as it seemed for a time. The behavior of many hereditary traits found by experimental and practical breeding resulted in the discovery that most such definitely diagnosable or measurable traits which are the basis of breed-improvement in plants, animals and man, are not based on single Mendelian units, but are instead exceedingly complex—like "giant molecules." They are hereditary—they run-in-the-family, but they are complex. Finding the rules which determine the inheritance of each such quality—whether structural, chemical, physiological or psychological—whether in plants, animals or man—whether in single-celled organisms or in the highest primates—still presents the great problem of genetics which deserves relatively more attention.

(4) THE GENE CONCEPT

The gene concept marks an important mile-post in genetical progress. A single gene can not be conceived as affecting only one somatic trait—one gene must certainly affect many somatic traits. Nor can one resultant in the soma be thought of as having been developed by or out of a single gene. Such a trait or somatic quality is the resultant of the interaction of a great host of genes, or chromosomal particles, if that definition be held for the time being.

There are now two senses in which the word "gene" is used, each of which is essentially different from the other. First, the gene may be conceived of as the smallest physical particle of the chromosome—possibly visible under the best microscope. Second, the gene may be thought of as the chemical and structural forerunner in the fertilized egg of a given trait or quality in the adult. Tracing the development of this gene to the quality itself in the adult is a long process, and, in its very early stages, has never been satisfactorily accomplished without serious gaps. Such a gene must be responsible solely for one trait and none other in the mature body.

But, as earlier stated, most of the qualities of the adult which are measurable or definitely diagnosable and are of use in plant and animal breeding and in human genetics and eugenics are not based upon a single or only a few genes, but more likely upon many hundreds of genes. Thus the effect of one gene or hereditary determiner is not constant, but is conditioned and determined by the particular combination with other genes in reference to the time and place of these unions as well as the chemical nature of the genes themselves.

(5) THE GAP BETWEEN THE GENE AND THE PRIMORDIUM

There is at present a long gap in our knowledge along the stretch of developmental sequence from the gene to the first sign of a definite tissue or organ in the embryo. What is and where is the thing which represents the subsequent trait, tissue or organ from the time it was last seen, as a gene in the germ cell or fertilized egg, until its reappearance as the "anlage" for said quality, tissue or organ in the embryo? This long gap leaves the relation of the gene and the chromosome to heredity still without its major support. Success in this field seems clearly to demand a joint attack by genetics and embryology. Embryology seeks continued sequence in development.

Biology demands still further collaborative research to find out whether the chromosome and its constituent genes (or at least the giant molecules or colloidal particles that appear to be genes) actually develop into or are otherwise responsible for the somatic traits or organs, as the science of cytogenetics now postulates. Even if no such "gene — trait sequence" were found, each of the basic sciences concerned would profit substantially by a collaborative hunt and each would continue to constitute a basic science in its own right.

The major joint task for genetics and embryology during the next period of scientific study is work in this particular field. If, ultimately, such joint studies work out as postulated by the cyto-geneticist, and numerous high points in this series are found, then the theory of the gene would stand as a principle, essentially in its present form, even if modified in detail. But if, after long search, such a "gene—trait sequence" could not be found, then the theory of the gene would be greatly weakened, and some other major explanation would have to be found for the mechanical basis of the heredity-pattern and also for the things and processes which might be found in the present developmental gap.

(6) THE FUNCTIONS OF THE NUCLEUS

The chromosomes have three primary functions: (1) to reproduce themselves exactly and thus insure continuity of the germ-plasm; (2) to prompt and guide the individual ontogeny to its somatic end; and (3) as a major body of molecules in the cell to give chemical and structural character and specific physiology to the cell as a unit in some highly specialized organ.

In duplication exact maintenance of chemical and structural character must be maintained in one cell-generation after another. In ontogeny the cell, beginning with the fertilized egg, must have the potentiality of developing along definite lines under definite conditions, but in its somatic end-tissue the nucleus, then highly specialized, has lost the power to reproduce itself, has reached a "blind alley," so to speak, but is vitally essential physiologically to the organism. The salivary glands of the fruit-fly are a good example of such a "blind alley." These several functions of the nucleus, along with the functions of the cytoplasm, are major fields for current genetical study.

(7) THE MEASURE OF HEREDITARY TRAITS AND QUALITIES. YARDSTICK INVENTION

Because most of the traits or qualities which concern organic evolution and heredity—and consequently are the basic elements with which mate-selection and the creation, rise and disappearance of species depend—are not single Mendelian units, nor even small groups of such units, but in the body of the individual are structural or functional qualities which for their somatic development depend upon the interaction of great masses of genes, such fact does not eliminate the necessity to describe and to define as a whole the somatic trait or quality under consideration; then to apply to it the principles of identification and diagnosis; then to apply the yardstick for its definite measure. This is no small task. It must be remembered that it required several thousand years of hard study by the whole human race to invent the more elementary yardsticks for the basic qualities of time, weight and distance—the c.g.s. system of modern physics.

The measure of a hereditary quality in the individual may be accomplished by one of the following ways: (a) Mathematical yardstick; (b) Matching-standards; (c) Description — definite diagnosis and case history.

Genetics can make no substantial headway unless the hereditary quality in the individual is measurable or diagnosable with some degree of definiteness. Of course, the ideal situation would call for the application of an accurate mathematical yardstick, which would measure exactly the degree of development of the subject-trait in a relative scale from zero to one, or on an arbitrary but absolute scale of equal accuracy.

Lacking such a yardstick, the next best genetical standard might be called the "matching-standard" in which a complicated anatomical or physiological or psychological quality of definite development is described, or a picture of it is set up as a standard against which the appearance of the same quality in a particular individual in a particular pedigree may be matched. The group of such matching-standards should comprise at least "two, three or five" or preferably more definite structural or conditional degrees of the same thing.

The third type of measure or standard might be called simply the definite diagnosis and case history. In this case the individual is described as having the quality or having it not. In the case of human stature, if the yardstick in inches or centimeters were lacking, and there were no individual against whom the particular measured person could be matched for height, the subject might be described for height as (1) dwarf, (2) short, (3) medium, (4) tall or (5) giant. In the development of yardsticks for genetical use it is well, with the lack of a mathematical yardstick, to proceed toward definite standards—advancing from descriptive classes, to matching-standards and, finally, when possible to the mathematical yardstick.

In genetical research great stress has quite properly been placed upon chromosomal study, but not enough upon the exact quantitative measurement or description or classification of those definite somatic qualities which are known to run-in-the-family. Practically it is necessary to know to what extent hereditary qualities can be broken up and recombined in heredity. It is necessary also to find the actual "breeding-units," whether or not practical breeding has yet learned to segregate them.

The whole matter of measurement comes in at this point. It is necessary first to measure the somatic end-product with which we are concerned both in theoretical study and in practical breed-improvement. Sir Francis Galton, one of the real founders of modern statistical science as an important department of applied biology, particularly in his use of mathematics as a research tool, was fond of saying:

> Until the phenomena of any branch of knowledge have been submitted to measurement and number it can not assume the status and dignity of a science.

(8) TRUTH AND PROBABILITY

The philosophers have fought long and valiantly over the question: "Do natural phenomena obey exact laws down to the very remotest and infinite detail, or does the creative principle itself require a breach of this behavior and thereupon place consciousness, appreciation and purpose as essential elements in the scheme of things?"

In nearly every field of scientific research the two principal things, when exactness is desired, are first the yardstick and second, the principle of probability. The Mendelian principles which have added so much to our knowledge of nature's behavior in heredity, were based upon ratios which occurred, in certain cases, within a definite probability. But in the field of mathematical analysis, there exists temptation to base conclusions upon the weak foundation of too few numbers and too little exactness of observed fact. Discovery of biological truth may be hampered as greatly by inappropriate or too much mathematical analysis as by the sacred postulates of over-orthodoxy or by pre-drawn conclusions. The investigator, if not extremely careful, is apt to provide one function by analysis, then to take this and build other functions upon it. Thus the temptation is to use derived values instead of observed data as the basis to which the investigation comes back very frequently in its search for truth.

Nevertheless, there is a new and general appreciation of the principles of probability. For a long time it was thought that biology and inheritance were non-mathematical sciences; that physics, chemistry and astronomy were mathematical or exact sciences. It is found now that physics, chemistry and astronomy are less exact mathematically, that is, they depend more upon probability-mathematics than formerly thought, and that, moving in the other direction toward a common ground, the biological sciences, by depending more upon probability, are becoming more mathematical.

(9) THE GENERAL FORMULA OF HEREDITY

Mathematically stated, the main problem of genetics runs as follows: Given a measured quality in each of a certain group of near-blood-kin, by what probability will the pre-indicated offspring possess this same quality within a definitely measured class-range? Successful prediction in such a case depends mathematically upon the location of the fluctuation-center of measurable values in the thing-predicted and the narrowness of fluctuation above and below this center. The more exact the fluctuation center and the narrower the range of fluctuation, the better the prediction, and the more certainly will the computed probability be found to point toward truth.

All genetical predictions by mathematical analysis which seek a general rule of nature's behavior depend ultimately, as for example the Mendelian studies do, upon the somatic ratios of the given quality among certain definite near-blood-kin.

$$(10)\quad K = f(M, R)$$

This is the general mathematical picture of nature's behavior in transmitting a trait or quality from one generation to the next.

$K = f(M, R)$, that is, K is the probability that, with a given M or measured quality in a given ancestor as the prediction-basis, the measured value of this same quality in the offspring will fall within the value R ± one half the selected class-range.

Next to its biological basis the main thing in genetical study is mathematical analysis. In this latter field the purpose is to test postulates and to construct the best possible mathematical picture or pattern for tracing the behavior of nature in the transmission of measurable or diagnosable qualities from one generation of living organisms to the next. While $K = f(M, R)$ is the mathematical statement of the general formula of heredity, it is necessary in the case of each definitely measured trait in each species to find out just what these two functions are and how they work together. This has been done for the quality of racing capacity in the Thoroughbred horse. This quality, which is highly hereditary—it runs-in-the-family, after being definitely measured in the individual could be investigated most profitably from the genetic point of view.

(11) THE PROBABILITY-RESULTANT

With this quality of racing capacity in the Thoroughbred horse it was possible to consider the matter of independence and synthesis of evidence. In this case the pattern formula of heredity —$K = f(M, R)$—first applied to the resemblance of measured racing capacity in the sire to measured racing capacity in the foal (all other near-kin being randomly represented), furnishes one definite element or piece of evidence.

Similar studies were made for each of the several nearest-blood-kin; it then became possible and feasible to work out the probability-resultant of all such pieces of independent evidence for the prediction of racing-capacity value for the offspring of any given specific set-up or group of near-blood-kin. Thus, given any pedigree set-up in reference to the same measurable or countable quality, and working out standards as the consequences of the analysis of at least 1,000 cases for each kinship, genetics has the basis for applying the general or pattern formula to the specific quality, and is thus able to compute the specific probabilities of given offspring-values when the measure of the subject-quality is given for each of the several near-blood-kin.

(12) OTHER GENETICAL NEEDS

While the evolutionary aspect of genetics as a controlled laboratory experimental problem is making headway, the coordination between genetics and both the paleontological and the more recent histories of the species of plants and animals have been relatively neglected. Similarly the collaboration of the laboratory geneticists with the practical breeders and improvers of plants and animals has been permitted to languish.

The two main characteristics of a living organism are reproduction and development. Of these the more fundamental is reproduction. In development a primitive cell may make undifferentiated colonies, then later may create specialized tissues and organs, but always the essential germ-plasm—the primitive cell—remains behind and is continuous. The most striking thing about a living cell is that its chemical activity, instead of creating some desired structure or starting a peculiar train of development (this is ontogeny), starts a train of chemical and structural reactions, the end-product of which is the exact duplicate of the cell which started the whole train. Thus the life cycle is represented in (a) reproduction of the germ cell, and in (b) the bizarre blind alley of somatic ontogeny. Genetical studies must keep this in mind always.

Still another relatively neglected field concerns the single-celled organisms, which have a different genetics from the many-celled species. The germ-cell and the somatic cell in single-celled organisms are the same. Thus single-cell genetics offers a field of research which should be pursued more extensively as a well-integrated unit of study within the field of genetics.

One degree down the scale of living forms below the single-cell organisms brings us to the virus, which now seems to be proven to consist of definite chemicals, the unit of which is a giant molecule of some sort. This molecule seems to have one of the main essential properties of living matter in that, under proper environment, the virus-molecule can duplicate itself, like a catalyzer or enzyme which makes itself. The relation of the behavior of the viruses, as recent discoveries have shown, offer a promising lead for more fundamental studies in the common field of bio-chemistry, pathology and genetics.

(13) THE RELATION OF GENETICS TO OTHER SCIENCE

If genetics fulfils its basic purpose, its fundamental researches will always be made in two fields: First, in experimental breeding and, second, in the study of natural evolution. Among the most essential tools needed for the interpretation of genetic data found by experimental breeding are the techniques worked out by the allied sciences of cytology, biochemistry, embryology, mathematics, paleontology and natural history. Pathology, psychology and education should be included in this list of critical sciences of use here.

The relation of genetics to eugenics is very close, but eugenics can not be looked upon as merely a branch of genetics. At the beginning of the century, along with the development of genetics as a science, and inspired mainly by the work of Sir Francis Galton and his colleagues, the general rules of heredity began to be tested for definite traits in man, and thus the foundation was laid for eugenics as "the study of all agencies under social control, that may improve or impair the racial qualities of future generations either physically or mentally."

(14) RELATIVE EMPHASIS AND PROFITABLE TRENDS IN GENETICS

While genetics and eugenics have not always followed and are not now emphasizing equably what are probably the most profitable phases of research in both pure and applied fields, still their net work has been exceedingly profitable in the discovery of truth, and to list the main lines only, the following fields of study are becoming more equably emphasized by research institutions and colleges:

Researches on:
(a) The basic Mendelian principles. "The theory of the gene." Specific cases.
(b) The chemical and physical nature of the gene.
(c) The biochemistry of genetics and development. The hereditary or constitutional aspects of immunity and susceptibility.
(d) The induction of mutations, and the manipulation of chromosomes.
(e) Bridging the gap by a more continuous picture between the gene and the first sign of the specific structure or organ in embryological life.
(f) Yardstick invention and more definite diagnostic descriptions of traits and qualities, whether by measure, or by clean-cut definition, or by matching standard.
(g) The construction of correct mathematical pictures which show how nature behaves in the control of genetical processes, looking to the discovery of generalized rules which may tie up still more closely the predictable somatic ratios in pedigree-analysis with the reproductive and developmental machinery.

BEGINNINGS OF FISH TERATOLOGY, 1555-1642

BELON, RONDELET, GESNER AND ALDROVANDI, THE FATHERS OF ICHTHYOLOGY, THE FIRST TO FIGURE ABNORMAL FISHES

By Dr. E. W. GUDGER
BIBLIOGRAPHER AND ASSOCIATE CURATOR OF FISHES, AMERICAN MUSEUM OF NATURAL HISTORY

INTRODUCTION

FOR the present writer it all goes back to a certain afternoon in the autumn of 1901, when, a graduate student at the Johns Hopkins University, I sat at work in the general laboratory of the old biology building at the corner of Eutaw and Little Ross Streets in Baltimore. I was working late dissecting the head of a skate to get the blood vessel system, and what I found was not "like the book." Inexperienced, I worked and worried (all by myself) but could not find the blood vessels with bends and curves and positions as described and figured in "the book" I was using as a guide—and I became considerably disturbed.

My equanimity was not heightened by the fact that about every fifteen minutes the janitor, who was wanting to close the laboratory and go home, would come to the big double doors, jingle his keys suggestively and look at me reproachfully. Each time I hurled objurgatory remarks at him and each time he retreated. Finally, however, footsteps came and halted in the doorway. Exasperated at both skate and janitor, I said in no very pleasant tones: "Confound you, Gardner! I'll quit and go home. I can't get the darned thing to agree with the book."

Then I was paralyzed by a mild voice which said, "What's wrong, Gudger? Maybe I can help you." And looking around I saw Professor E. A. Andrews. Thirty feet away was a chute to the lower regions through which we dumped the debris of our dissections for disposal in the furnace. Had it not been so distant and so small, I think that in my extreme embarrassment I should surely have risked this rapid transit *ad advernum.*

Professor Andrews then came over, looked at my dissection showing the course of the blood vessels, and said: "The figures in the book you are using may be made from a specimen dissected by the author, but more likely they are generalized diagrams intended to fit the majority of cases. What you have is a very interesting abnormality, a marked departure from the normal." That settled the question for me, and from that day till this, I've been looking for such departures from the ordinary and it is great sport.

ABNORMAL FISHES FIGURED IN THE OLD FISH BOOKS

The beginnings of our knowledge of any phenomenon in natural history go far back in the past, and the ultimate origins can of course never be found, but the proximate ones sometimes can. Who first figured fish abnormalities can not be stated, but I have found who first published figures of such. Into this history I purpose leading my readers, in the hope that they may share my interest in this "good hunting."

Eighteen years after the episode narrated above I came to the American Museum as editor to bring to completion Dr. Bashford Dean's great "Bibliography of Fishes." Before his untimely death, my distinguished predecessor, Dr. C. R. Eastman, had brought out Volumes I and II and had most ably begun a very fascinating section of Volume III, the "Pre-Linnaean" literature of fishes. This was to be a special bibliography of the old published writings on fishes from the *editio princeps* of Pliny's "Historia Naturalis" from the press of J. Spira at Venice in 1469 to the appearance at Stockholm in 1758–59 of the two volumes of the tenth edition of Linnaeus's "Systema Naturae" This great work on the nomenclature of animals, in its tenth edition is everywhere accepted as the international date line in zoology, separating the old from the modern, and establishing recognized names for animals and plants as of that date—1758–59.

This "bibliographing" the old literature of fishes opened to me a most fascinating field for exploration and study, and into its wide expanse I have in the years since 1919 made many happy incursions. Into one little corner of this little explored territory—that marked "Teratology or Study of Abnormal Fishes"—I now purpose taking the reader in the strong hope that he may find in it some of the interest I have

In the first quarter of the 1500's, and indeed in the brief space of 15 years (1507–1522), there were born in southwestern Europe five men who were destined to set new standards for the study of natural history in the western world. Of most interest to me is the fact that these five established the science of ichthyology on the deep and broad and solid foundations on which we are building to-day. Of these men (Belon and Rondelet, Frenchmen; Gesner, a German-Swiss; and Salviani and Aldrovandi, Italians) and their work and books on fishes I have given some account in *Isis* (1935, vol. 22, no. 63, pp. 21–40, 5 portraits). Here and now I wish to show that four of them (all unknowingly) first figured and described abnormal fishes, and—375 years later—started the present writer in an extensive study of all sorts of fish abnormalities. Perhaps these beginnings may have some interest for the reader even as for the present writer.

A SALMON WITH A HOOKED LOWER JAW, 1553

The first of these old naturalists, Pierre Belon, published in Paris in 1551 the first book ever devoted to fishes and having such a title page. Only ten fishes are described and figured—in crude but perfectly recognizable wood cuts—the first published figures of fishes known to me. However, the greater part of the book is given to the "Daulphin," to the hippopotamus and the nautilus—since in those early days all water dwellers were grouped together. Really the fishes are the smaller part of the book.

Two years later Belon published an enlargement of this work with a quaint title as follows:

Petri Bellonii Cenomani
De aquatilibus, Libri duo
Cum eiconibus ad viuam ipsorum effigiem, quoad
eius fieri potuit expressis.
Ad amplissimum Cardinalem Castillionoeum
Parisiis.
Apud Carolum Stephanum, Typographum
Regium.
M. D. LIII.
Cum privilegio Regis[1]

After another two years, Belon published as his ichthyological opus the third, the enlarged and final edition in his native French. The title is as follows:

La nature et diversité des poissons
avec leurs pourtraicts representez
au plus pres du naturel.[2]
Paris, 1555.

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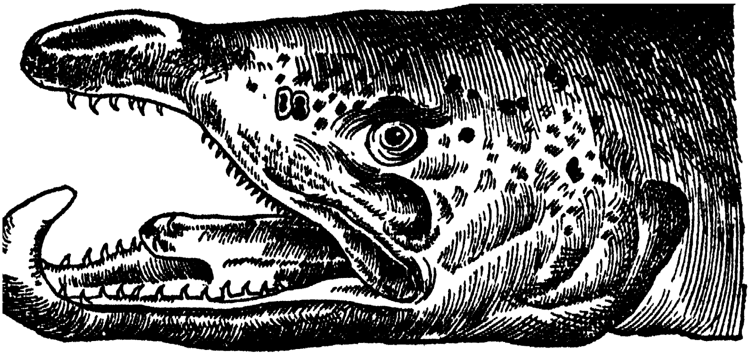
[1] Of Pierre Belon of LeMans
Two Books Dealing with Aquatic Animals,
With Effigies of These Drawn
As Near to Life as Possible
[Dedicated to] The Most Renowned
Cardinal Castillione
[Published] at Paris
At the Printing House of Charles Estienne,
Royal Printer.
1553
With the Permission of the King.



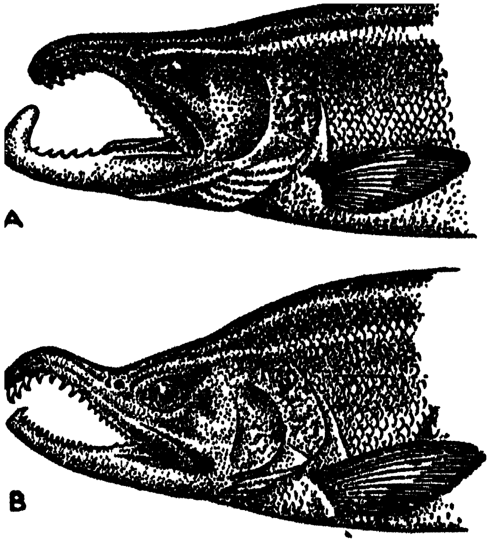
—After Pierre Belon, 1555

FIG. 1. THE HOOKED LOWER JAW

OF AN OLD MALE EUROPEAN SALMON. THIS IS THE FIRST PUBLISHED FIGURE OF A FISH ABNORMALITY.

These, the earliest books on fishes, are so old, so rare, and so valuable that they are literally "worth their weight in gold." Belon, who was an "all-round" naturalist, wrote other books on natural history subjects. His book on birds contains on opposite pages skeletons of bird and man with the like bones identified and labeled—the first known figures in comparative osteology. But let us return to the fishes, where our particular interests lie.

In both the 1553 and 1555 works, Belon figures the head of an old male salmon with the deformed upper and characteristic hooked lower jaw, as is to be seen in Fig. 1. This he thought to be the head of a female salmon, from which we may judge that he did not dissect his fish, since we now know that these de-



—After J. R. Norman, 1931.

FIG. 2. HEADS SHOWING HOOKED JAWS

AT BREEDING SEASON OF (A) A MALE EUROPEAN AND (B) A MALE PACIFIC SALMON.

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[2] The Nature and Diversity [Variety] of Fishes
with their Portraits Represented
as Near to Nature as Possible
Paris, 1555.

formed jaws are found on the male salmon only. The upper jaw in the Atlantic salmon undergoes only a moderate degree of deformity, as may be seen in Fig. 2A. But, as the drawing shows, in the Pacific salmon (Fig. 2B), the upper is even more deformed than the lower. Belon makes no remark on this deformity, and hence one may judge that he thought this the normal female head.

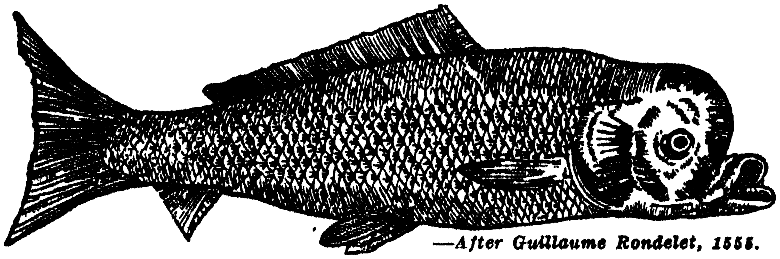
Little is known as to the cause of this abnormality. It is a secondary sex development at the time of reproductory activity. It develops at this time—at about the age of four years—in the Pacific salmon, and after spawning these fishes die. This is not true of the Atlantic salmon, which for a fish has a relatively long life span. Hence this curiously hooked lower jaw is very characteristic of old male Atlantic salmons, as may be seen in Fig. 2A. At the front of the upper jaw, in these salmons there is a groove formed in which the point of this hook fits.

The function of this peculiar hook is still in dispute. It was at one time thought that the male used it in making the so-called "nest" in pebbles and sand for the reception of the eggs. Then it was found that the female without a hook does most of this work. Next it was believed that the hook was used by the male to hold the female in spawning, but this idea also has been abandoned. Of it Smitt, the Scandinavian ichthyologist, writes: "The least violent explanation appears to be that the hook is an essentially pathological appearance, characteristic of age, but produced [in part] by the irritation caused by blows of the snout, both during combats and in leaping over obstacles."

It should be emphasized that this is the first published figure of a salmon with the hooked lower jaw, and the first figure ever published of a teratological (*i.e.*, deformed) fish. As such it is worthy of having particular attention called to it.

A PUG-HEADED CARP, 1555

The second of our old ichthyologists was Guillaume Rondelet, regius professor and for the latter part of his life chancellor of the famous old medical school of Montpellier. This is only a few miles from the Mediterranean Sea, whose fishes Rondelet described.



—*After Guillaume Rondelet, 1555.*

FIG. 3. RONDELET'S PUG-NOSED CARP.
THE FIRST PUBLISHED FIGURE OF THIS ABNORMALITY.

In 1554, Rondelet published at Lugduni[8] in quarto size his "Libri de Piscibus Marinis," in which 244 fishes are described and nearly all figured. In 1555, Rondelet published (also at Lyons) his "Universae aquatilium Historiae pars altera, cum veris ipsorum Imaginibus," which is a continuation of the 1554 work and is bound with it. In this book he figures salmons with faint beginnings of hooked jaws. Some of his figures are crude and several suggest abnormalities, but I can not be sure save of one of a carp now to be noted.

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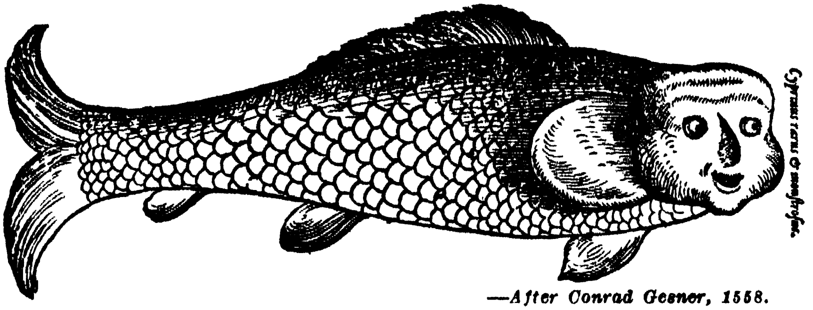
[8] Lugduni Gallorum—Lyons of the Gauls in France—is to be distinguished from Lugduni Batavorum—Leyden of the Batavians in Holland. Both cities were book-publishing centers of great activity in the 1500's.


Cyprinus rarus & monſtroſus.

—*After Conrad Gesner, 1558.*

FIG. 4. GESNER'S "CYPRINUS RARUS & MONSTROSUS."

THIS IS PRESUMABLY AN ATTEMPT TO PORTRAY A ROUND-HEADED CARP.

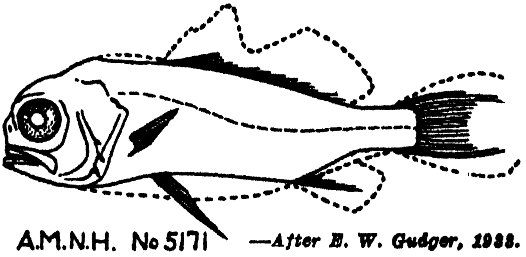
His "Cyprinus of a wonderful kind" (Fig. 3 herein) is the first published figure of a pug-headed fish. This fish, which our old doctor purchased alive at a fish market in Lyons, puzzled him greatly. It had the body, tail, fins, eyes, scales, etc , of a carp, but it had a bulging forehead and a very short upper jaw. Still, however, it was a carp, but as he thought and called it, "of a strange kind . . . with a snout like a dolphin." This abnormality bears characteristic designations as Bulldog-head, Pug-head, Lion-head; Tête de chien, Bouledogue Tête; Löwenkopf and Mopskopf—in the English, French and German languages, respectively. But in all cases the name applies to a fish with an abruptly rounded forehead, a very short upper but a normal lower jaw.

This fish looks as if its head (exclusive of the lower jaw) had been "pushed in" by strong frontal pressure, the upper jaw having almost disappeared, while the lower remains normal. This abnormality is due to the fact that, because of some internal disturbance (probably glandular) during development, the long bone forming the base of the skull fails to develop normally. This basal bone either fails to grow to normal length or it elongates but buckles up in the eye region, causing marked exophthalmia (protuberant eyes). In either case this ties down the bones which form the upper jaw and the anterior part of the skull, and results in the formation of the bulging forehead and abbreviated upper jaw.

This is the first published figure of a carp with a bulldog head, and the second of an abnormal fish. However crude some of Rondelet's woodcuts of fishes are, it must be said that this figure is a very good one—comparing favorably with some recent ones of this same abnormality in the carp. This, however, can not be said of the next abnormality to be considered.

A ROUND-HEADED CARP, 1558

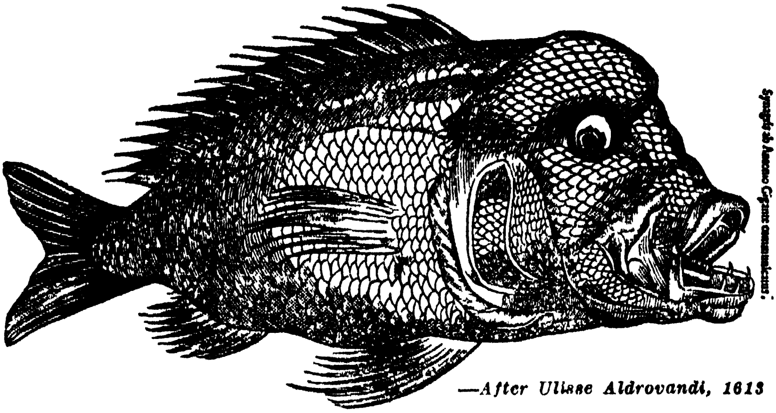
Conrad Gesner, a German-Swiss, because of his great erudition was known as the German Pliny. This cognomen



—*After E. W. Gudger, 1938.*

FIG. 5. A SMALL ROUND-HEADED MARINE PERCH (NATURAL SIZE).

was based in part on the publication at Zurich from 1551–87 of the five huge folio volumes (the last posthumously) of his great encyclopedic "Historia Animalium," in which was contained all that had been published up to his time plus all that he had learned of the natural history of animals in his travels and studies. Of this "Liber IIII"—"De Piscium & Aquatilium Animantium Natura"—is devoted to fishes and other water animals. These are arranged alphabetically and treated *in extenso.* Many of his figures and much of his data are taken from Belon and Rondelet—especially the latter.



—*After Ulisse Aldrovandi, 1613*

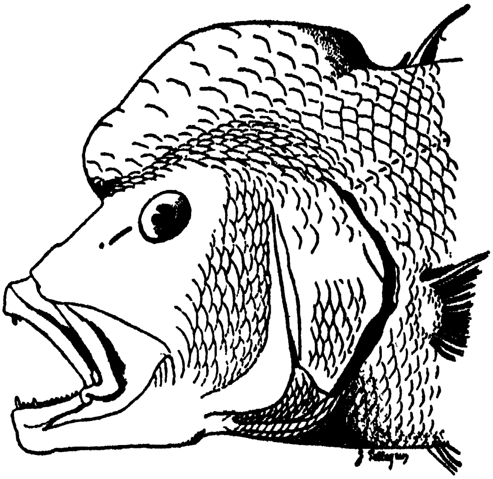
FIG. 6. ALDROVANDI'S FAT-HEADED SEA PERCH.

THE FIRST ILLUSTRATION OF THIS CURIOUS ANOMALY.

Gesner lists Rondelet's "Cyprinus mira specie" and gives his description. He declares that a similar pug-headed carp had been sent him by the classical scholar and writer Gilbertus Cognatus (Cousin), of Nozeroy in France, who had taken it in 1543 in a swamp and had kept it alive in an aquarium (the second alleged case of such—recall Rondelet's live specimen). The other was taken in Brandenburg, Germany, in 1546. This he did not receive, but he had a drawing of it sent to him by Johann Thannmyllerus of Augsburg. These fishes Gesner says were similar to Rondelet's, but he does not figure either fish, nor, after reproducing scores of Rondelet's other figures, does he reproduce the figure of the pug-headed carp. However, as we shall see in the next section, he goes Rondelet not "one" but "several" better.

Gesner on p. 373 of his Liber IIII figures what he justifiably calls a "Cyprinus rarus & monstrosus." That he was wise in his choice of title may be seen on observing the fish portrayed in Fig. 4. Gesner also did not have this fish in his hands but only a painting of it sent to him by Achilles Pyrminius Gasserus, a physician of Augsburg. He expressly says that this fish, taken in November, 1545, from Lake Constance near Retz in western Austria, had a face like a human in forehead, eyes, mouth, nose, cheeks and chin. Another drawing of another similar malformed fish, taken in October, 1545, from the river Eirs near Retz, was sent to Gesner by Raphael Seiler, another Augsburg doctor. This drawing showed another carp which in its features "omnia effigie humana habuit."

Gesner's Latin is not easy to decipher, but I believe that I am quoting him correctly. He reiterates that these fishes were carps in everything but the front part of each head. These in forehead, eyes, nose, cheeks and chin had each a human aspect. And these things are just what are portrayed in Fig. 4.



—*After Jacques Pellegrin, 1901.*

FIG. 7.

A RECENT DRAWING OF ALDROVANDI'S FISH (*Dentex vulgaris*) WITH A HUMPED FOREHEAD.

It is not easy to explain this figure. Gesner was not given to credulity; on the other hand, his attitude was for his day thoroughly scientific. However, he evidently gave full credence to his correspondents. Note that both fish were taken near Retz in western Austria in successive months in the same year. It seems probable that there was but one fish. Gesner did not have the fishes themselves, only the drawings. Both drawings come from Augsburg, and it seems possible that one was a copy of the other. Some of the figures for his book were made by Gesner himself, the others in his house under his eye. But the woodcut of the "Cyprinus monstrosus" was evidently reproduced from one or the other of the drawings sent him.

But what was the carp with the human face, which Gesner knew only in a drawing? I do not know, but I suspect that it was that form of abnormal fish known to teratologists as a round-head. In such fishes the whole snout and anterior part of the skull fail to develop. Baby fishes in early stages have such an appearance, in which the whole front of the head is precipitously rounded off. If this early condition should persist into adult life, through the failure to develop of the bones forming the base of the skull and both jaws—lo a round-head similar to Gesner's figure.

That the interested reader may know what a real round-head looks like, there is reproduced here as Fig. 5 a drawing of such a fish which I had made some years ago. This is a little round-headed silver perch, only 2½ inches long, which has carried over to this age the round head and big eyes of his babyhood. If Gesner's fishes (which he did not see) were round-heads, then, since Gesner reproduced the drawing sent by his friend, it is clear that the artist drew heavily not on the fish but on his very strong and vivid imagination. And his product was such a fish as never was on land, in river or sea.

The fourth of our earliest ichthyologists was the Roman physician, Hippolyto Salviani. He wrote only on fishes—on those from the waters adjacent to Rome. His folio is illustrated by 77 brass (not copper) plate engravings. In the Museum copy these plates printed in 1554–1558 are as fresh and clear as if they had been struck off 38 instead of 380 years ago. Not one of them, however, shows an abnormal fish, so with this brief notice we pass on.

A GIBBOUS SEA PERCH, 1613

Next we consider the first published figure of a fish which may be designated as a "gibbous-head," a "hump-head" or a "fat-head." The names, like the abnormality, are interesting.

The word gibbous comes from the Latin *gibbus*, meaning a hump. It is primarily an astronomical term applied to the moon between half and full when the limbs are convex. In fishes a "frontal gibbosity" is what may be seen in Fig. 6 of the fish which the Italian encyclopedic naturalist, Aldrovandi, figures and describes under the name

Synagris in his "De Piscibus" (Bononiae [Bologna] 1613). This curious abnormality is not uncommon in certain perciform fishes of both fresh and salt water—of the families Cichlidae in fresh water and Labridae and Sparidae in salt water. Most of these fishes were once grouped as Chromidae, so-called because of their bright colors.

Like the hooked lower jaw found chiefly or only in the adult male salmon, and in the Atlantic salmon generally in exaggerated condition in old males only, frontal gibbosity is found only in adult males (and in more exaggerated form in the oldest specimens) of various fishes of the families named. It is a strongly marked sex dimorphic character, which becomes greatly accentuated with age. Aldrovandi's Synagris has been identified as *Dentex vulgaris* Cuv., a fish found in the Mediterranean to-day. Indeed in Fig. 7 is presented a recently figured (1901) head of a gibbous *D. vulgaris* from this sea. Comparison will show how well Aldrovandi's artist "did his job."

This hump commences generally at the level of the eyes and is prolonged posteriorly on the "nape of the neck," sometimes almost to the first dorsal ray (Fig. 7). In some of the parrot-fishes (which have very short jaws) the frontal gibbosity is so far forward and so precipitous that the condition by the inexperienced might be thought a case of round- or pug-head. The form of the hump is very variable (see Figs. 6—in which it is drawn bi-lobed—and 7), but always it gives the fish a very bizarre physiognomy. The gibbosity in both Aldrovandi's and Pellegrin's drawings is a huge affair. Aldrovandi's seems to be bi-lobed, though possibly this is poor drawing; while Pellegrin says that in one specimen the hump measured fully one third the length of the fish.

This body is a sort of fatty tumor found only on males and is best developed in old or possibly senile individuals. Its function is not positively known. One suggested function is that of storage against a time of scarcity. By some it has been compared to the "fat bodies" of amphibians, and thought to supply material for the manufacture of sperms at breeding time. This could be tested by observing gibbous fishes for a diminution of the hump at breeding season in an aquarium. So far as I know this has not been done.

To stout and stolid unimaginative persons of plethoric habit, of whose gray matter one has little opinion, the term "fat-head" is opprobriously applied. I submit that the fishes portrayed in Figs. 6 and 7 have something of this look. If not on this account, then certainly on bearing in mind the composition of this hump, one is perfectly justified in calling these fishes "fat-heads."

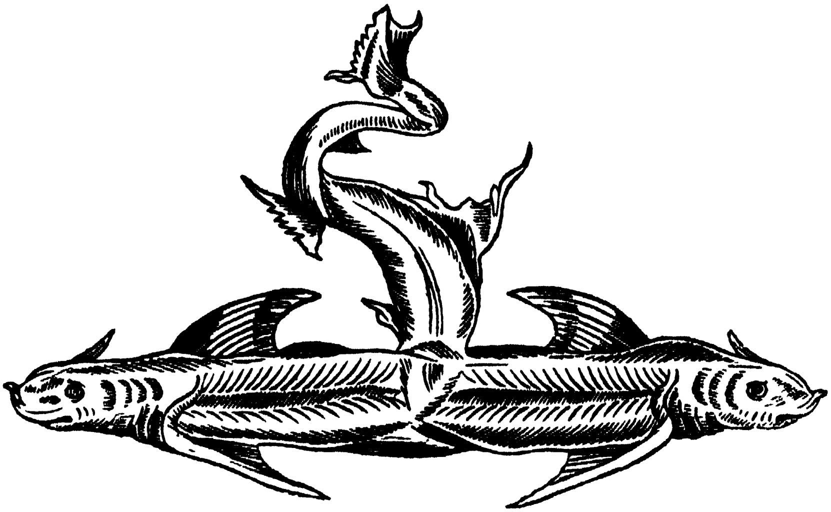
Aldrovandi's drawing is certainly the earliest published figure of this abnormality. Belon in his work published in 1554 figures a little fish called *Galerita,* which has on its head a hump which I have viewed with much suspicion. Belon says that "When alive there is on the top of its head a soft erectile crest blue in color." Day, the eminent British ichthyologist, figures and describes a little fish, *Blennius galerita,* with a pair of branched tentacles above and between the eyes. This may be Belon's fish and his figure merely one of bad draughtmanship—but it surely excites considerable suspicion in me.

If any reader of this article is interested enough, he might care to see the text and figures of an authoritative article by Dr. Jacques Pellegrin, the well-known ichthyologist of the great Muséum d'Histoire Naturelle in Paris. His "Les Poissons à Gibbosité Frontale" may be found in the *Bulletin de la Société Philomathique de Paris,* 1901 (pp. 81–91, with 5 interesting figures).

Before taking up the figure of the next teratological fish (and the most interesting), which is also by Aldrovandi, it will be of interest to speak briefly of the man. Like the other four he was a doctor of medicine and for long years was professor of natural history at Bologna. His motto through life was "Nothing is sweeter than to know all things." And so well did he live up to this motto that it finally came to be said of him that he was the "modern Pliny" (Gesner had died before Aldrovandi had reached his great eminence) and "the most inquisitive man in the world [of his day] with regard to natural history."

A Two-Headed Shark, 1642

Last on our list but not least in interest is Aldrovandi's figure of a two-headed, or semi-Siamese twin, shark. This is not found in his book on fishes ("De Piscibus," Bononiae, 1613) but in his book on monsters—"Monstrorum Historia" (Bononiae, 1642, p. 428). This "Piscis Biceps" is a two-headed shark, possibly a dogfish, and the placing of it not in the book on fishes but in that on monsters plainly indicates that Aldrovandi or his editors (Ambrosinus and Bernia) recognized it as an abnormality.



—*After Ulisse Aldrovandi, 1642.*

FIG 8. A TWO-HEADED SHARK "FROM THE RIVER NILE."

THE FIRST PUBLISHED FIGURE OF A BICEPHALOUS FISH.

All this led to his outlining a plan of a brobdingnagian encyclopedia of natural history. To this and to his museum he gave his fortune and all the long years of his life. His "Opera" comprise 13 great folio tomes. Five or six were published before his death in 1605 or 1607, the others were brought out later by his associates, pupils and friends. These works like Gesner's contain practically all natural history from Aristotle down to his day. They are source books of enormous value. Much of the materials (drawings, etc.) of his books and museum are still to be found at Bologna and elsewhere in northern Italy.

To Aldrovandi's museum in Bologna came animal curiosities from all over the world, and among them the "Piscis Biceps." This our old natural history book states was caught "in the River Nile in Egypt not far from the town called Latislana." There is much discrepancy here. Sharks are marine fishes and the Nile is fresh water. This double-head might have been taken in one of the Nile delta distributaries if this were brackish. But the tides at Alexandria rise but a few inches and the volume of the Nile is great. As to the town Latislana, the only one I can find trace of is or was in Italy.

Another doubtful thing is that this dicephalous shark was "almost equal in size to a crocodile." If so, it must have been a very small "crocodile on the bank of the Nile." Two-headed shark embryos are sometimes found, but after hatching their swimming is so impeded that they are quickly devoured—by voracious fishes, including sharks, and possibly their own hungry parents. But whether the specimen was large or small, it is a two-headed shark, the oldest ever figured, and so far as I know the only one figured until about 1824—182 years later.

Like Gesner's artist, who took great liberties in drawing his round-headed carp, so Aldrovandi's painter likewise let his imagination run away with him. He has surely exaggerated his specimen. He had drawn this shark in the shape of a T—each head standing out at right angles to the trunk. All the double-headed shark embryos in the figures I have seen and all two-headed fish of any kind which I have examined are Y-shaped. Aldrovandi's unknown artist may have had a T-headed specimen, but like my Scotch ancestors I "hae me doots."

The explanation of the origin of two-headed animals is a very obscure and complicated one. It is most easily observed and studied in fish eggs in hatcheries. But even in the study of such eggs much controversy has raged. Hence it does not seem wise to lumber up a popular article with obscure technicalities

It may be of interest to state here that the library of the American Museum is the fortunate possessor of every one of the works referred to herein, and that it also has all the natural history works of each author—*in first editions* and also in versions in other languages and in later editions. Some of these books are so rare that they are literally "worth their weight in gold."

It is interesting also to note that four out of the five early naturalists in the earliest books on fishes figured and after some sort of fashion described abnormal fishes. That they did not know that they were abnormal (except in the case of the two-headed shark) is not to be charged against them, for their figures of these fishes are before us. Without knowing it, they started the science of teratology of fishes, and it is their due that credit should be given them.

Just here the reader must understand that such adult abnormal fishes are relatively exceedingly scarce even in these days when vast catches of fishes are made. Witness the relatively few forms that have been figured and described by scientific men. Witness also my own case—the few that have come to me during the past ten years when friends—anglers and commercial fishermen—have been on the watch-out for these for me, all along our north Atlantic coast.

There are several reasons for this. Although relatively considerable numbers of teratological fishlets are hatched, most die in babyhood (if one may speak of such for fishes) too handicapped to withstand the ordeal of development. Because their physical deformities handicap their movements, most of those that grow to be fingerlings are readily snapped up by marauding voracious fishes. This high mortality allows but few to come to maturity, and these few escape the angler generally and in commercial catches in nets are lost in the multitude of entirely normal fish. More credit then to these old ichthyologists that in the very beginning they picked out, as did Belon first of all (in 1553), fishes "of an extraordinary kind."

SOME EFFECTS OF ANIMALS ON PLANTS

By Dr. WALTER P. TAYLOR

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It is recognized that all animals depend, in final analysis, on plants. It is coming to be more widely appreciated also that plants in turn depend on animals to a very considerable extent; that process and practice in farming, and especially in wildlife administration, range management and forestry, must increasingly take this reverse dependence into account if well-rounded and satisfactory results are to be obtained.

It is particularly desirable that these animal relationships to plants be known and applied as adequately as possible in the extensive national program of reforestation, range rehabilitation, erosion control and natural resource conservation now going forward. We should try to anticipate difficulties from animals likely under certain conditions to be inimical to seeds and seedlings, whether of range plants or forest trees; and we ought to take full advantage of those animals that may be counted on to assist in these colossal enterprises for the restoration of our exploited areas. The need is not for "total protection" of so-called "beneficial" species, nor for "eradication" of "pests" but for scientific management of all wildlife, in accordance with an enlightened understanding of what Allee has called the geo-bio-ecology of each locality.

In this paper the writer makes an attempt to explore some phases of the relationships involved.

(1) Grass Eating

A very practical aspect of the influence of animals on plants is their work on forage on the open grazing range. Problems involved affect no less than 1,055,000,000 acres of land in the United States, or 55 per cent. of the total area of the country. It has been estimated that grassland occupies 13,000,000 of the 52,000,000 square miles of land surface of the globe. It is not impossible, as one writer states, that "Human life has been and is more dependent upon grasses than upon any other group of living beings." The conservation and proper maintenance of these vast and valuable grassland areas are of vital importance probably to a majority of the world's population.

Under original conditions all forms of life were components of an organic-inorganic unity fluctuating rather widely but continuing to function successfully and practically in balance over long periods of time. Under the aegis of man's supremacy, however, natural equilibria have been disturbed. Through artificial and abnormal processes, among them grazing, fire, elimination of native species, introduction of exotics, cultivation, fertilization, irrigation, drainage, game preservation and some other processes, the original balance is upset. It is safe to say that all inhabited portions of the earth have been modified. The new conditions favor some wild species, eliminate others. Some of the results: Temporary vastly enhanced productiveness of land through agriculture (considered broadly to include not only farming but wildlife management, range administration and forestry); accelerated erosion, both by water and by wind; shrinking water supplies for domestic use and irrigation; forest, range and wildlife depletion; and soil exhaustion.

New problems arise in almost exact proportion to the disturbance and interruption of original conditions. Certain species of birds, rodents, lagomorphs, ungulates, insects and other animal forms, previously kept in bounds by an adequate environmental resistance, now become positively inimical to man's interest. Others become highly useful. Some are beneficial at certain times and places, harmful at others. No hard-and-fast catalog of "good" and "bad" species can be made. The entire biological spectrum is altered and study of the bio-ecology of the grassland community becomes the most important activity in which man can engage on the plains, prairies and savannas of the world.

(2) Overgrazing

The evil effects of overgrazing have been commented on since the dawn of history. In our own country as early as 1872 a report of the United States Department of Agriculture pointed out that native grasses were disappearing from the prairies of Texas, especially on bottomlands, "depasturing" of cattle being destructive to them.

E. D. Ball estimates that insects, including leaf-hoppers, grass-hoppers and others, cut down the available forage —principally grass—on the best ranges in the vicinity of Tucson, Arizona, by 20 to 30 per cent.

Our own investigations have dealt with the lagomorphs and rodents, principally in Arizona. Results of sample plot clipping studies made by McGinnies and the writer on the Santa Rita Experimental Range showed that the antelope jack rabbit (*Lepus alleni*), the banner-tailed kangaroo rat (*Dipodomys spectabilis*) and certain small species of lesser importance consumed or accounted for 28.7 per cent. of the total vegetation and 38.8 per cent. of the total valuable forage grasses. It was found that grass constituted 24.1 per cent. of the food of the Arizona jack rabbit (*Lepus californicus arizonae*) and 45.0 per cent. of that of the antelope jack rabbit for the year. Four-years sample plot tests at Coconino, near Grand Canyon, Arizona, showed that, under the conditions of the experiment, prairie dogs consumed 69 per cent. of the wheat grass (*Agropyron smithii*) and 99 per cent. of the sand dropseed (*Sporobolus cryptandrus*), or 80 per cent. of the total potential annual production of forage. Results of a one-year experiment at Williams, Arizona, showed prairie dogs accounted for 83 per cent. of the blue grama (*Bouteloua gracilis*).

Admittedly these plot studies are highly incomplete and partial. So many factors are involved that the results must not be pushed too far. But they do afford a quantitative suggestion of the potential work of certain rodents and lagomorphs under particular conditions.

It is perfectly obvious that the work of grazing animals may profoundly affect the vegetation cover. Clements is authority for the statement that the general apparent replacement of tall grasses (of the type of *Andropogon* and *Stipa*) by short grasses (like *Bouteloua* and *Bulbilis*) in the mixed prairie regions of central Nebraska, Kansas and elsewhere in that region is explained by the effect of grazing. The buffalo is assumed to be the original agent responsible for the elimination of the tall grasses and their replacement by buffalo grass — appropriately named ! — while domestic live stock in more recent days continued and accentuated the trend toward short grasses.

Ground squirrels are destructive to forage grasses in many localities. Thus Grinnell and Dixon estimate that 750 Oregon ground squirrels during the growing season of pasture grass eat as much as one steer. It is further estimated that the population of California ground squirrels (*Citellus beecheyi beecheyi*) takes the place (in that state) of 160,000 cattle or 1,600,000 sheep. A part of their green feed is grass. In Arizona it has been estimated, on the basis of cage food tests, that on the average 15 antelope jack rabbits will eat as much good forage, chiefly grass, as a sheep, and 74 as much as one cow; while of the smaller Arizona jack rabbit, 30 will eat as much as one sheep and 148 as much as one cow.

Kashkarov and Kurbatov noted the part played in the Kara-Kum Desert in middle Asia by long-toothed ground squirrels (*Spermophilopsis leptodactylus*). These rodents dig up the sand to procure the bulbs of *Poa bulbosa,* their main food. The number of holes aggregate 13,135 per hectare. Where *Poa bulbosa* is absent, the squirrel feeds on the roots of *Aristida pennata.* The sand is loosened and begins to move. "Then the rodents migrate to another place." The assumption is that these activities appreciably reduce the carrying capacity and promote the drying of the desert. Seemingly in Russia as elsewhere ". . . man and his domestic animals are responsible for the formation of the worst kind of desert." The relationship to rodent damage of overgrazing by the camels, sheep and goats brought in by man has not been worked out. In arid areas of the southwestern United States, we find that, in many places, as overgrazing becomes apparent, some rodent depredations tend to become more serious.

Hill, of the National Forest Service, believes that in the vicinity of Tucson, Arizona, heavy grazing by domestic live stock, noticeably accentuated in recent years by native forage-feeding species, as the kangaroo rat and jack rabbit, was doubtless the greatest contributing factor in the change from a short grass and browse type to a vegetation characterized by less palatable and hardier desert plants.

Too much emphasis can hardly be given to considerations of grazing by domestic live stock. The stocking of our ranges with millions of cattle, horses, sheep and goats has had and is having a profound effect not only on the grasses but on all forms of vegetation and all animal life in the biotic communities affected. The question still presses for answer: How many domestic live stock can be supported on a given area without deterioration of the forage resource and the soil? Scientists, range users, owners, entire communities, are vitally interested. Doubts have even been expressed regarding the adequacy of an economic system which places chief emphasis on private profits without regard for the future productivity of the resources utilized (see, for example, the discussion of the responsibility of foresters by Silcox).[1]

Another question may often become pertinent: "To what extent is it economically feasible to control the rabbits, rodents and insects which often become troublesome feeders on native grasses?" In some localities the answer is obvious with little preliminary study. In others the value of the resources at stake, the ability or willingness of the government or the private land-owner to cooperate by reducing domestic stock so the grass will have a chance to recover following the control operation, the present degree of injury to vegetation and soil and the proper use of the land from the standpoint of highest long-time use to the greatest number of people, all should be given consideration. Seeming overproduction, so troublesome at present (1936), emphasizes the undesirability of attempting to graze submarginal lands which should be left for upland game.

The further query arises whether any live stock grazing at all on some lands is not overgrazing. While wild grazing animals, such as the bison, pronghorned antelope, elk and some of the smaller forage-feeding species were in former times balanced, on the average, with the vegetation, it appears that on certain submarginal lands, at present, any increased pressure at all is too much. In such cases it is coming to be realized that funds spent for range rehabilitation, whether for seeding or planting, rodent control, weed control or erosion control, are likely to be in vain. An inviting alternative, in these cases, is to leave the land alone, let nature heal herself. In some localities game will come back, or can be restocked to advantage. Substantial values from native wildlife, watershed, recreation and scientific uses can be assured. The land can be turned into an asset instead of a liability.

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[1] *Jour. Forestry,* 33: 198–204, 1935.

The Biological Survey has shown that many animals, both birds and mammals, regularly prey on grass feeders. The work of insectivorous birds is very well known, but insectivorous mammals have been largely overlooked. The grasshopper mice, for example, consume 88 per cent. of animal food, chiefly insects. Coyotes, foxes, badgers and skunks feed extensively on rodents and insects Much rodent damage is directly proportional, within limits, to artificial range disturbance. Evidence is accumulating also that if grazing use is conservative, the range user will have far less trouble with weeds, insects and rodent pests than if he permits over-heavy use.

In this connection one should note that the so-called predatory and rapacious species, including such creatures, for example, as the coyote, bobcat, mountain lion and fox, are practically always favorable to plant growth, in that they help to keep down the number of forage-feeders, and doubtless sometimes prevent the occurrence of irruptions of rodents or other species which might otherwise occur.

Some rodents and insects seem to appear in increased numbers along with the weeds which become more numerous on overgrazed areas. On certain areas with which the writer is familiar the pressure of live stock is so great that overgrazing would have occurred regardless of the work of rodents. This is an important point in range management; for it will do very little good to control forage-feeding rodents if live-stock pressure is so heavy that overgrazing will take place anyway.

The seriousness of overgrazing is being increasingly recognized by all intelligent stockmen, who are insisting on the closer and more careful regulation of grazing use in the interest of the future of the industry. This point is clearly indicated by the enactment of federal legislation, such as the Taylor Grazing Act, having for its object the regulation of grazing on the public domain.

It is recognized that grazing is a normal process, without which, as a usual thing, the grasses and forage plants do not always prosper. Very old areas under total protection often deteriorate. While the causes of this tendency to go backward are not well known, it appears that the accumulation of dead stems and leaves, normally removed by grazing, handicaps the growing plant. Under original conditions the grazing use of our ranges by game and rodents was well adjusted to the maintenance of the vegetation.

It is unreasonable to expect that plants can withstand all the original pressure from the wildlife and a tremendous weight of domestic live stock, in addition, without serious and in some instances rapid deterioration.

On the other hand, on primitive or wilderness areas, where live stock is excluded, seemingly the aim should be to retain the native game and forage-feeding rodents, *for the best interest of the plants.* It is, of course, highly desirable also to keep a normal population of flesh-eaters, so the forage-feeding species of game and rodents will not become over-abundant.

(3) Eating Stems, Roots, Barks, Buds and Leaves

In certain localities animals that consume the bark, buds, leaves, seeds and roots of forest trees undoubtedly tend to favor the extension of grazing range at the expense of forest. The principal wild offenders are beetles and other insects, rabbits, hares, squirrels, porcupines, wood rats, mice, deer and other game species.

Between 1895 and 1905 a certain bark beetle destroyed a billion feet of timber in the Black Hills, and from 1918 to 1925 about 300,000,000 board feet on the Kaibab.

Porcupines work on forest seedlings and older trees, too; wood rats, in places, on natural reproduction of the forests. A lepidopteran larva was found in the Argentine that attacks the prickly pear. Imported into Australia, it has to a considerable extent brought this plant, a single species of which had become a serious pest over about 50,000,000 acres, under control.

Bark feeders include at least the following mammals: meadow mice, pine mice, pocket gophers, rabbits, hares, mountain beavers, wood rats, woodchucks, porcupines and beavers. Mention might well be made of a number of other squirrels, in addition to the woodchuck—and of the elk also, which sometimes feed extensively on aspen bark.

Rabbits are well known to exercise considerable effect on the vegetation—and so on all the organisms associated with it.

For hundreds of years surpluses of game have been recognized as exercising an appreciable effect on plant associations. In 1789 the French *Tiers Etat* made the assertion that the most terrible scourge of agriculture is the abundance of wild game. Overstocking with deer has been assigned as one of the causes of alteration of plant associations in England.

Some of our own experiences in America have emphasized the dangers of game surplus in no uncertain terms. Overpopulation of deer has developed on a number of the desert ranges and forested areas of the southwestern United States, and similar difficulties have arisen in Pennsylvania and other eastern states.

The situation on the Kaibab National Forest in northern Arizona has rightly been given a good deal of attention. The trouble seems to have been initiated in 1905, when President Theodore Roosevelt set aside a large portion of the Kaibab country for a game preserve. In the early days considerable numbers of cattle, sheep and horses grazed on the area, and numerous Navajo Indians hunted deer (*Odocoileus hemionus*) thereon for food. Also present in the region was an abundance of mountain lions and coyotes, natural enemies of the deer. The institution of the game preserve radically changed the status of the area. Grazing by live stock was reduced. The Indians were prevented from hunting. Flesh-eating mammals were restricted in numbers. Relieved from natural controls and unharvested by man, the deer population expanded from perhaps 3,000 or 4,000 originally present to a maximum estimated all the way from 25,000 to 100,000. Forest Service officials and others, including the writer, were impressed with the alterations taking place in the vegetation. In 1931 the Kaibab Investigative Committee concluded that the Kaibab was not producing more than 10 per cent. of the available and nutritious forage that it once did, and that if deer overgrazing continued the aspen-forest type would ultimately disappear from the Kaibab Plateau. The writer and others who have independently studied the problem were of much the same opinion.

It is probably not an accident that pretty nearly all the difficulties encountered in over-browsing by deer and other animals have arisen in connection with disturbances of one sort or another by man.

(4) Consuming, Disseminating and Storing Seeds

Probably few more important animal influences exist than those in relation to the seeds of plants.

Insects attack the seeds of various trees and other plants; tree squirrels, chipmunks, and at times other rodents, store and consume quantities of conifer seeds and sometimes cut off cones; mice of different species are avid consumers of the seeds of forest trees and of certain grasses of plain and desert; birds consume quantities of seeds.

Cage experiments conducted by the writer at Fort Valley, Flagstaff, Arizona, disclosed that the gray-collared chipmunk (*Eutamius cinereicollis cinereicollis*) will eat an average of 277 seeds of the ponderosa pine in each 24-hour period. An Arizona mantled ground squirrel (*Callospermophilus lateralis arizonensis*) under similar conditions will consume 338 pine seeds in a day. The minimum seed supply necessary to stock an area completely in one year under favorable climatic conditions has been estimated as eight pounds per acre, or 114,400 seeds. Four chipmunks and two mantled ground squirrels could eat the entire eight pounds in 64 days.

Plot experiments at Fort Valley have shown a marked effect on planted ponderosa pine seeds by birds (long-crested jay, red-shafted flicker) and probably also by certain mammals, especially the Arizona mantled ground squirrel, gray-collared chipmunk and tawny deer mouse. In a small plot open to birds and rodents 78 seedlings appeared; in a similar plot adjoining, protected from these species, 269 seedlings grew.

In 1928 G. A. Pearson and B. R. Lexen, of the Forest Service, in cooperation with Dr. Frederic E. Clements, of the Carnegie Institution, and the writer, initiated a test at Flagstaff, Arizona, to determine the influence of bunch grass on germination of ponderosa pine. This experiment has been reported on recently by Pearson.[2] The findings strongly emphasize the important rôle played by field mice (*Microtus mogollonensis*) in the yellow pine type of northern Arizona, where grass cover becomes heavy. Pearson's Table 1 shows some striking differences in the number of seedlings in the plots under protection from rodents as compared with those unprotected. On August 22, 1929, 1,781 seedlings were counted on the protected plots, 618 on the unprotected ones. On August 18, 1933, 100 seedlings had survived on the protected plots, 3 on the unprotected ones. As Pearson points out, rodents were abnormally abundant here as a result of protection of the grassy cover from grazing. Predatory enemies of the mice had also been reduced.

A number of writers have emphasized the difficulties associated with reforestation efforts as a result of the work of rodents. Clements concluded that the real importance of fire in the lodgepole pine forest lay in its removal of rodents for several years.

Observations in California, Michigan and elsewhere indicate a radical difference in rate of rodent reinvasion following fires in different localities. That size of seed is significant in relation to rodent damage was shown by a Canadian investigator, who pointed out that greater success was obtained in New Brunswick by using the small-seeded white spruce rather than the larger seeded white pine. More recently the same point has been emphasized by a number of Forest Service workers. These investigations are of unusual interest and potential value in connection with the emergency conservation work in reforestation now going forward under governmental auspices. All available data must be carefully taken into account, and additional information gathered, if the reforestation program is to succeed. Nor is the case always so simple as might perhaps be indicated by Pearson (*loc. cit.*), who recommends poisoning of small rodents through the summer and early autumn of a year of pine seed development. For many questions arise: What rodents are involved? Is rodent control on this particular area economically feasible? What species should be controlled? Over how large an area should control operations be conducted? What precautions should be observed to protect innocent or valuable wildlife? Like the problems of vegetation, those of animal life are extremely complicated. A good deal of additional study is needed. In every case a qualified wildlife research specialist should be called on for an opinion prior to the initiation of control operations.

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[2] *Jour. Forestry*, 32: 545–555, 1934.

Over considerable areas in northern Arizona live-stock grazing, especially grazing by sheep and goats, often supplemented by forage-feeding rodents, is bringing about the spread of junipers at the expense of the valuable grama grass cover. The grass is removed or weakened by grazing; the juniper seed passes through the alimentary tract of the sheep or goat and easily becomes established in grazed areas. In this case, contrary to that cited on a previous page, the forest (woodland) is being extended through biotic influence at the expense of grass cover. If the process continues long enough considerable areas of grass will be altogether lost to grazing.

A similar tendency for mesquite to "take over" grassland is strongly developed in certain areas in southern Arizona, for example, in the Empire Ranch country and on the Santa Rita Experimental Range. The influence of live stock and range rodents is apparently brought to bear in this case also. Cholla cactus, likewise, is spreading in southern Arizona. Cattle distribute the joints, wood rats often drop them en route to their dens, and these activities, associated with lessened grass competition resulting from heavy grazing, facilitate the spread of the cholla. Seemingly the most important component of this animal influence is live-stock pressure. In its absence the rodents would make little difference, one way or the other. Oaks and junipers are spreading in the hill country of Texas. It is probable that protection from fire and heavy grazing by live stock are the principal factors involved.

The writer does not want to leave the impression that the work of the native birds and animals in relation to seeding is all bad. Many years ago Barrows[8] called attention to the fact that for centuries birds have been recognized as one of the agencies in forest rotation and in resurfacing with vegetation tracts swept bare by wind, water, fire or man. The fruit and berry eaters function most effectively. Forbush has pointed out that birds destroy the fruit but plant the seed, being instrumental in extending the woodlands and thickets in which they dwell. McAtee, in a letter to the writer, points out that the crow, starling, waxwing, thrush, catbird and mockingbird are among the species that eject seeds from the mouth. He writes this is a trait of highly frugivorous species and of insectivorous species as well at periods when they resort to a fruit diet. "In the long run, the process undoubtedly is important among the means by which fruit-bearing plants are distributed."

Rodents assist in forest maintenance through caching of crops of Douglas fir seed in the surface soil, distributing black walnut and other nut-bearing species of oaks, hickories, etc., and planting western yellow pine in Montana, Idaho and Oregon. The red squirrel is a replanter of the hardwoods, and one observer has expressed the opinion that its service as a forester far outweighs the little harm it does.

Any one who has traveled in the area and given some attention to the matter must realize that the pine squirrel has a far-reaching influence on the trees in the Canadian Zone forests of the mountains of the West. In the fall it stores great numbers of pine cones and pine seeds, so that collecting from seed hoards is a recognized method of securing seed for planting. One Forest Service worker asserts that the caches of small red squirrels average about two bushels, but not uncommonly reach 8 to 12 bushels of cones; and there are reports of up to 40 bushels of western white pine cones having been found stored in a single spot, presumably by one squirrel It must often happen that seeds are planted by this instrumentality. It is scarcely to be doubted that these squirrels, although they eat the seeds, are important in the maintenance of the forests in which they dwell. Finally McAtee, of the Biological Survey, asserts definitely that birds are indispensable agents in the natural dissemination of trees which reproduce themselves by fleshy fruits and nuts and that they aid also in reseeding coniferous trees. It should be remembered that detrimental animal effects are easy to see, while beneficial effects have to be carefully worked out through research. Most of our "practical" treatment of these problems is based on superficial observation. As soon as we can we ought to complete our studies of all these things scientifically through well-planned, well-financed and well-manned research.

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[8] Rept. Chief Div. Ornith. and Mamm. 1890, 1891: 280–285.

In crossing the state of Texas in September, 1927, Clements, Tharp and the writer were impressed with the obvious importance of mammals and birds in relation to distribution of vegetation. One would like to know the precise vegetational history of the region. Western elements, including the mesquite, palo verde, prickly pear and snakeweed, were noted just after crossing the Brazos River, well in the eastern third of the state. Apparently the clearing of the oak-hickory woods was a first step in the far eastward spread of these western species. The influence of animals must also have been considerable. The buffalo may have helped to seed up some of the clearings with mesquite. Assuredly the introduction of Spanish horses and cattle accelerated the process. Overgrazing, to which many areas have been subjected, has assisted the spread of western scrub, through the wide-spread breaking up of the grass cover, consequent reduction in grass competition and easy establishment of scrub seedlings.

Very much in evidence, particularly through central Texas, was the frequent limitation of young shrubs to a circle over the ground surface dominated by the crowns of trees, in this case mesquites and oaks. The evidence indicated that the seeds had been planted by birds using the mesquites or oaks as perching places. An incomplete list of these bird-disseminated plants included *Zizyphus* sp., *Condalia* sp., *Lycium* sp , mesquite, wild grape, *Smilax bona-nox, Celtis reticulata, Berberis* sp., *Rhus trilobata, R. virens, R lanceolata, R. toxicodendron, Xanthoxylum* sp., *Adelia* sp. and *Koeberlinia* sp. All of them, it will be observed, are suitable for bird food.

Over vast areas in western Texas are to be found mesquite savanna and desert plains. This type of semi-arid land prevails from approximately Odessa, Texas, through New Mexico to about Sentinel, Arizona, where it gives way to extreme desert. It is becoming clearer that in some places over this great area, perhaps over most of it, grazing animals, supplemented by forage-feeding rodents and rabbits, have tended to suppress the grasses and disseminate scrub. Birds and certain mammals have helped to spread the shrubby species. Relicts show unmistakably that in places, at least, grassy desert plains formerly prevailed where now the relatively worthless semi-desert holds sway. Apparently a similar deterioration is taking place in other localities over the earth's surface. For example, in speaking of the Kara-Kum Desert region, the alert Russian investigators, Kashkarov and Kurbatov,[4] have rather pathetically remarked, "The northern Tertiary plateau is slowly changing into a sand desert." Responsibility for the steady encroachment of desert in these various cases seems to belong to man and his grazing animals rather than to the native wildlife.

(5) FERTILIZATION

The innumerable and complex adaptations by means of which flowers secure cross-pollination through the agency of insects are among the most marvelous phenomena known to the biologist. While some plants are adapted for cross-pollination ". . . by wind and water, the majority of flowering plants exhibit profound modifications of floral structure for compelling insects (and a few other animals, as birds or snails) to carry pollen from one flower to another." Evidently the dependence of flowers on insects, on certain birds and on a few other animals, is so great that they have, in a manner of speaking, gone to extraordinary lengths to acquire the necessary adaptations to benefit from the visits of these pollinators.

The pollinating functions of bees and moths are pretty well understood. Birds as pollinators are less well known. Ornithophilous flowers include a considerable variety of plants, principally in the tropics. Among genera which are in part at least bird-pollinated are *Marcgravia, Norantea, Poinciana, Strelitzia, Protea, Feijoa* and *Erythrina.* Birds involved include principally hummingbirds, sun-birds and honeysuckers. One worker considers birds to be by far the most important agents in the pollination of flowers in Western Australia. He thinks they are the chief if not the only efficient pollinators of the genus *Eucalyptus.* The bird-pollinated flowers of *Erythrina variegata,* common along the Java coast, are visited by 26 different birds, as well as by squirrels!

(6) SUMMARY OF EFFECTS OF ANIMALS ON PLANTS

One should not permit the animal difficulties which so often result from disturbance of an area by man to blind him to the fact that animals make numerous and necessary contributions to plants. Adams once said the relations of game to forest constitute a permanent and not a temporary alliance. We can go further and say that the relations of animals to plants and both to their mutual environment constitute a permanent and not a temporary alliance, everywhere that normal community relationships exist.

It is easy to see the dependence of flowering plants on the animals that pollinate them. Less easy to visualize perhaps, but possibly even more important, are the numerous other relationships in which the welfare of the plant population is dependent on animals.

Animals assuredly could not live without plants—but plants probably could not, except in artificial environments, live without animals.

The following suggestions (not in the order of their importance) indicate, in a somewhat sketchy way, some phases of the relations of animals to plants in a terrestrial environment. It should be noted that the extent, the quantitative significance and the important details of these relationships, remain, in most cases, to be worked out.

(1) While under original conditions native animals were in balance with vegetation, disturbances of various kinds by man, such as grazing by domestic stock, fires, lumbering, cultivation, etc., have altered the status of the original resident species. The equation in every disturbed locality is a new one, requiring for its solution careful consideration of local as well as general factors.

(2) Grass consumption by insects and vertebrates is considerable, and in some instances serious.

(3) Eating by animals of the stems, roots, barks, buds and leaves of plants is also significant. The work of bark beetles, of herbivorous rodents, of rabbits and of certain game species is sometimes spectacular and of no small moment in certain localities.

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[4] *Ecology,* 11: 35–60, 1930.

(4) The ingestion, transportation, storage and involuntary planting of seeds is of enormous significance, sometimes detrimental to man's interest, probably in most cases beneficial.

(5) It is impracticable and undesirable to classify wild species of animals as "bad" or "good." The number of individuals of the species in question, surrounding conditions, time and place, make so much difference that each problem, whether of conservation or control, should be considered by itself and by a group of competent workers, including specialists in the wildlife field.

(6) Animals depend, in final analysis, on plants, but plants also depend to a considerable extent on animals.

(a) Plants must depend to a considerable extent on protozoa, crustacea, worms, insects and vertebrates to help form, fertilize and cultivate the natural soil so that it will be a suitable substratum for their growth.

(b) Flowering plants depend on fertilization by animals for their continued existence.

(c) Forest trees depend to a considerable extent on those animals which help to plant their seed and spread them. Forest rotation and reforestation are often carried forward by the seed-eating animals.

(d) Brushy and herbaceous plants depend to a considerable extent on birds and other animals for their dissemination. Revegetation is often largely dependent on these animals.

(e) Nearly all plants depend to a certain extent on animals (flesh-eaters, birds, insects) for protection from other animals (chiefly insects and rodents) which attack the bark or other parts of the plant.

(f) Plants sometimes owe their persistence to some extremely injurious animal influence, which benefits them because it injures their competitors slightly more. Dwarf grass-heath, in East Anglia, has been cited in illustration of this.

(g) Plants may depend on animals for a part of the carbon dioxide they breathe.

(h) A few plants depend on animals for a part of their food. Examples, the Sundew, the Venus's flytrap, etc.

(i) Marsh plants and meadow plants and later plants of dry environments often depend on the beaver for the natural "reclamation project" of which they are beneficiaries.

(j) Some plants, particularly grasses, depend on animals for the removal of surplus parts, dry stalks, etc. Moderate natural grazing releases the plants and permits them to grow more strongly than would otherwise be the case.

(k) Plants depend to a certain extent on herbivorous animals for assistance in keeping their own plant numbers down so that unwieldy surpluses and disastrous over-population are prevented.

(7) The present day nation-wide operations of the federal and state governments in reforestation, erosion control, recreational development and range rehabilitation emphasize more than anything that has ever happened in American history the need for more adequate knowledge of the interdependence of animals and plants and their relations to their environment. Liberal investment in geo-bio-ecological research would doubtless help prevent losses and would be sure to return big dividends in more successful conservation.

JAMES WATT: A SCIENTIST RATHER THAN AN INVENTOR

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ASSOCIATES IN MECHANICAL ENGINEERING, UNIVERSITY OF ILLINOIS

It is generally thought, even by many engineers, that James Watt originated or invented the steam-engine. This is far from true; what Watt really did was to develop a slow-working, cumbersome steam pump, excessively wasteful of fuel, into a quick-working, powerful and efficient steam-engine and finally left it virtually as it is to-day. The writers propose to show that this development by Watt was the result of a most careful, thorough and scientific research involving the properties as well as the economical use of steam.

The use of steam for power purposes, however, dates much farther back than the period when Watt lived. The elastic power of water vapor must have been familiar to man from the earliest periods of our history. The first recorded observation of the application of steam appears to have been made about one hundred and thirty years before the Christian era by Hero,[1] the Elder. No other mention of steam as a prime mover occurs in the works of ancient authors, nor among more modern writers until about the year 1563, when Mathesius[2] hints at the possibility of constructing an apparatus, similar in its operation and properties to those of the modern steam-engine. Many men who made improvements either in its construction or application have been credited with the invention of the steam-engine. The result of the best of these improvements was embodied in the Savery engine of 1699. The Savery engine was a pumping engine, essentially the same as the simple injector of to-day. The limits of the engine and the inventors' hopes for it may be expressed by a quotation from Savery: "For," he says, "I will raise you water 500 or a 1000 feet high, could you find us a way to procure strength enough for such an immense weight as a pillar of water of that height; but my engine at 60, 70, or 80 feet, raises a full bore of water with much ease."

The next important development was that made by Newcomen, who, in 1705, developed an atmospheric engine containing a piston. The use of atmospheric pressure as the motive power necessarily resulted in a large engine (see Fig. 1). The Newcomen engine aroused a controversy, because it infringed on Savery's patent. This atmospheric engine was improved in various details by many eminent men, being finally brought to its apex by Smeaton in 1772. In spite of these improvements it was a more expensive form of power than that of horses, because it used large quantities of fuel and steam. These engines were so wasteful that they used about one half of the steam that was generated for them, to warm up the cylinder and piston on each stroke. It was the realization that such a condition was not only extremely wasteful but unnecessary that prompted James Watt to make a thorough study of the steam-engine.

After complete research and experimental consideration of steam and the existing forms of steam-engines, Watt wrote the specifications for a new design radically different and of such superior economy that it deserves lasting recognition. The history of mechanical engineering can furnish no other example of so great an improvement having been

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[1] "Pneumatica"—Hero.

[2] "Sarepta"—Mathesius.

achieved by a single individual. Watt's developments were the progeny of his own fertile brain, and were brought to perfection by his own sagacity and perseverance. Before relating the steps which he took in the creation of his marvelous achievement, it is desirable to review his personal history.

James Watt was born in Greenock, Scotland, on January 19, 1736 From boyhood he suffered ill health and at an early age he displayed a superior genius for mechanics. After spending three years in apprenticeship as a mathematical-instrument maker in London, he returned to Glasgow where he was later employed at the University of Glasgow as a mathematical-instrument maker. Watt read extensively and studied quite thoroughly metaphysics, chemistry, architecture and most of the modern languages He was well liked and associated with the most eminent men of that time in Scotland and England As a result of such self-education he was a man of true philosophical mind and conversant with all branches of science.

It was while at the university that his research and experimenting with steam really began. It is said that his attention was turned to the powers of steam in 1759, when Dr. Robinson of the university proposed to him some ideas relative to wheel carriages. However, nothing developed concerning such an apparatus. Up to this time Watt was not familiar with steam nor the steam-engine, as he had confined most of his time to the making of mathematical instruments.

There is evidence which proves that Watt was a man of unusual ability and was, therefore, ably fitted to cope with involved problems beyond the field of his immediate interest. For instance, after repairing a model of the Newcomen engine in 1763, his natural activity of mind rendered this model a subject of profound meditation, and led him into a course of practical inquiry respecting it. He found that most of the trouble in this engine was due to the fact that too much of the heat in the steam was lost by heating the cylinder. This loss he found could not be eliminated in the engine in its original state, since it was necessary to cool the cylinder in order to condense the steam. Watt realized the difference in conductivity and heat capacity between wood and cast iron, so he tried to overcome this disadvantage by building an engine with a wooden cylinder. This idea was soon abandoned, but it did have its compensation, as it led him to study the properties of steam, as to pressure, temperature, elasticity, weight, concealed heat, etc.[3]

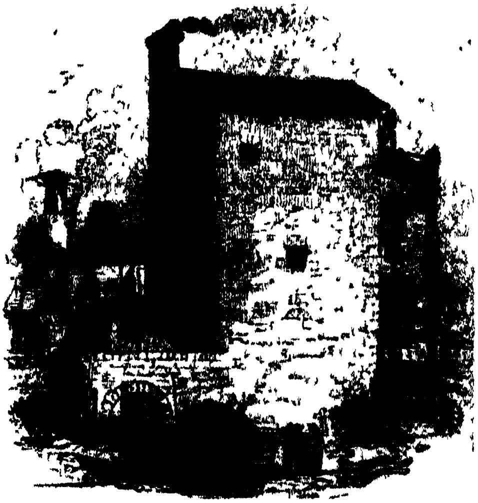

FIG. 1. ATMOSPHERIC ENGINE

FROM "THE STEAM ENGINE," BY D LARDNER. 1840.

Here again we have another instance of Watt's very active philosophical research that terminated in an important practical result, for he found that at atmospheric pressure a pound of steam contains 960 heat units. This was indeed a large quantity, and therefore he thought that the economical use of the steam should be the guiding factor in engine design, rather than the boiler and furnace, which had been the main objectives in former designs. This information allowed Watt to reach this all-important conclusion to make the best use of the steam—the steam cylinder must be kept as warm as possible and condensing the steam must be done outside of the cylinder. He did not make use of this, his great idea, until 1765, when he conceived the idea of a condenser separate from the cylinder. This indeed, as we know now, was marvelous reasoning, but he did have difficulty, namely, how was he to get rid of the air and injection water? This latter problem apparently did not worry Watt a great deal. The method he intended to use to overcome this difficulty can be seen in the words of part of his first patent of January 5, 1769:

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[3] For further discussion as to the methods Watt used, see "Treatise on the Steam Engine," by Farey, pages 311 to 313.

> Firstly, that vessels in which the powers of steam are to be employed to work the engine, which is called the cylinder in common fire engines, and which I call the steam-vessel, must, during the whole time the engine is at work, be kept as hot as the steam that enters it.
>
> Secondly, in engines that are to be worked wholly or partially by condensation of steam, the steam is to be condensed in vessels distinct from the steam-vessels or cylinders, although occasionally communicating with them. These vessels I call condensers.
>
> Thirdly, whatever air, or other elastic vapour is not condensed by the cold of the condenser, and may impede the working of the engine, is to be drawn out of the steam-vessels, or condensers by means of pumps.
>
> Fourthly, I intend, in many cases to use the expansion force of the steam to press on the pistons, in the same manner as the pressure of the atmosphere is now employed.

From these statements one can see that Watt's chief interest was economy and that he was obliged to state the properties of a machine that had never been built. Although he knew the merits and truth of his deductions, he did not know how he was to execute them in the form of an actual engine. His patent does not describe a machine, but merely states methods for decreasing the engine's steam consumption.

About the time Watt obtained his patent, he became associated with Dr. Roebuck, who had started the Carron iron works in Scotland. They proposed to start manufacturing engines extensively under the patent. Watt started his first real engine, which had a cylinder diameter of 18 inches, at Kinneal-house. This was an experimental engine, and was, therefore, altered and improved from time to time before it was finished. The greatest difficulty in the construction of this engine occurred in the boring of the cylinder and in the packing of the piston to make it steam-tight.

While Watt was contending with these obstacles that impeded his progress, Roebuck became financially embarrassed, from the failure of his undertaking in the Borrowstowness coal and salt works, and was unable to continue with the engine manufacture. In 1773 Roebuck sold his interests to Matthew Boulton, of Birmingham, whose metal works was the most complete in England. This meant much to Watt, especially since a portion of the works was allotted to him in order that he might carry out his ideas on a grand scale. It was at this plant that the engine reached its final form, as shown in Fig. 2.

The thermal efficiency of Newcomen's best engine as obtained from its operating data was about 1.5 per cent. This may be compared with the thermal efficiency of Watt's engine which can be estimated from the fuel consumption, which was one-hundred weight of Wednesbury slack and lump coal, while the engine made 3,000 strokes and at each stroke raised 7.8 cubic feet of water 24 feet high. With these values the thermal efficiency is about 3 per cent., which is

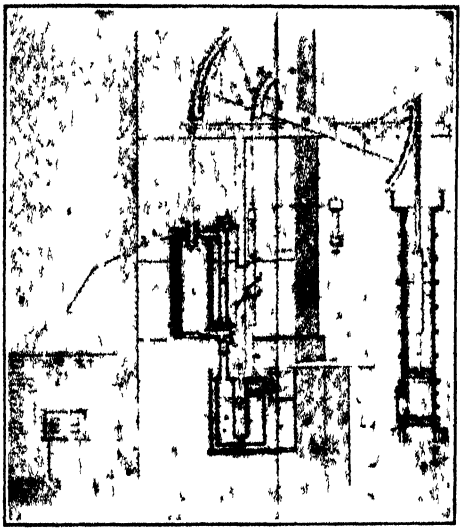


FIG. 2. WATT'S FIRST STEAM PUMPING ENGINE.
FROM "A MANUAL OF THE STEAM ENGINE," BY R. HOBLYN. 1842.

indeed a remarkably high value for this early engine and is by far the highest value for any engine of that time.

In making the changes of plant location and the necessary improvements on the engine much time was required; as a consequence the patent was about to expire and the engine was not yet placed on the market. Watt, therefore, applied for an extension of time on his patent, and in 1775 an act was passed to extend the original patent of fourteen years to twenty-five years from that date; so that in the whole the patent was in force more than thirty years. The granting of this extension in itself speaks well of Watt's work and the merits of his engine. The writers have been unable to find any other record where such an extension has been made on any other patent.

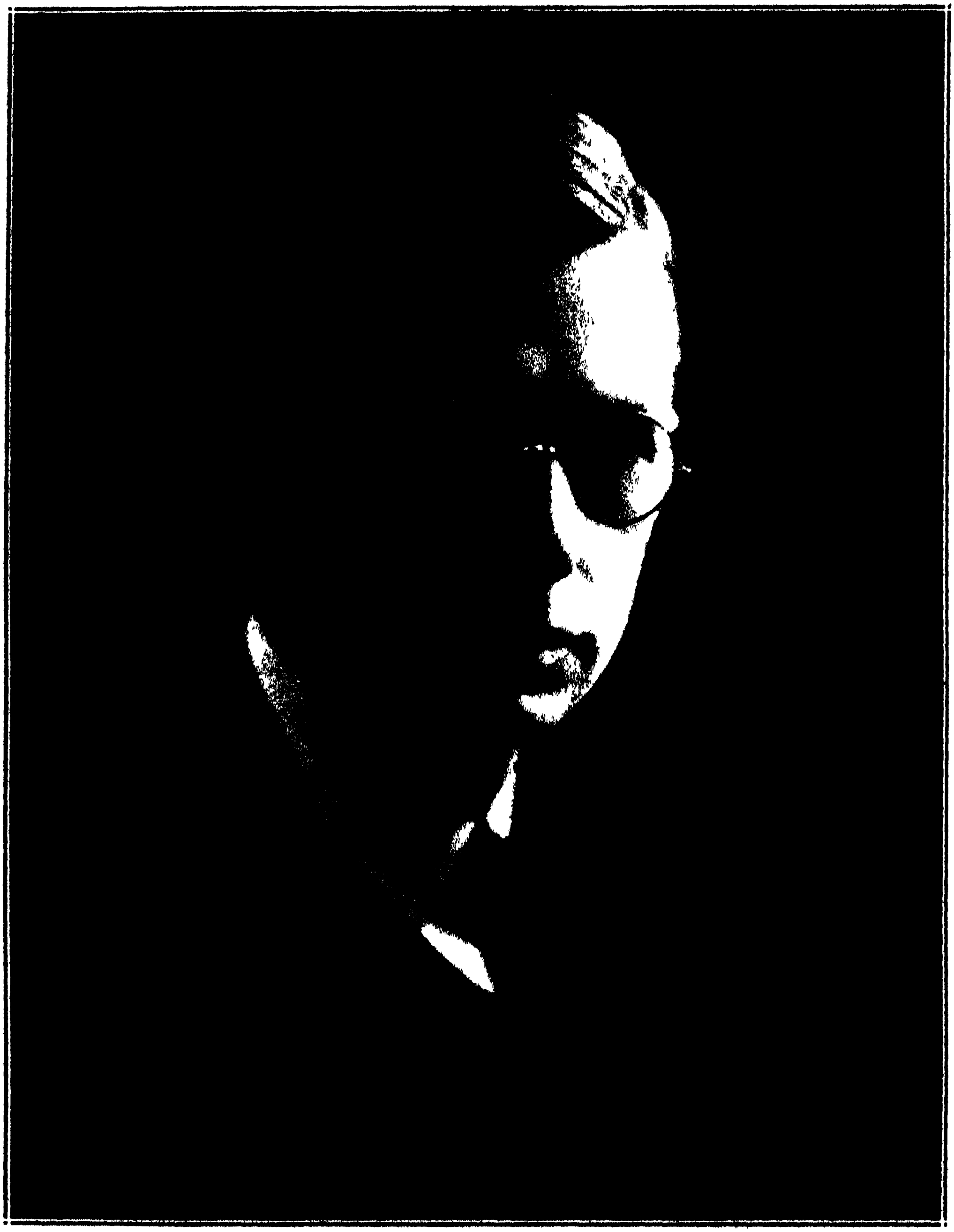
The tremendous commercial success of Watt's engines was not due entirely to his own efforts, but depended largely on the business judgment and experiment of his esteemed partner, Boulton, who wrote to Smeaton in 1778 as follows:

> We are systematizing the business of engine making, as we have done before, in the button manufactury; we are training up workmen and making tools and machines to form the different parts of Mr. Watt's engines, with more accuracy, and at a cheaper rate than can possibly be done by the ordinary methods of working. Our work shop and apparatus will be of sufficient extent to execute all the engines which are likely to be soon wanted in this country; and it will not be worth the expense for any other engineers to erect similar works, for that would be like building a mill to grind a bushel of corn. . . .

The chief, if not the only, sales arguments for the Watt engines were their unusual records for operating economy as compared with the Newcomen engines (already in service) in the use of fuel. For example, he states that "all we ask from those who choose to have our engines is the value of one-third part of the coals which are saved by using our improved machines instead of the old. . . .

In conclusion, it may be said that, before Watt's time, the steam-engine was exclusively a steam pump, very slow working, extremely cumbersome and excessively wasteful of fuel. His first improvements made it quick-acting, powerful and efficient, but still left it a steam pump, entirely replacing the Newcomen engines. James Watt's later developments and inventions adapted the steam-engine to drive machinery of all kinds and left it virtually what it is to-day. Later designs have developed more direct methods of (1) connecting the piston with the crank, (2) higher working pressures and (3) compound expansions; all of which were considered by Watt.

James Watt is also credited with the following developments: condensing steam-engine; double-acting steam-engine; steam cylinder jacketing; expansive working of steam; piston stuffing box; wet air pump (air and condensate pump); circulating pump; indicator; mercury steam gauge; fly-ball governor; throttle valve; stroke counter; steam hammer, and statuary copying machine.



Bachrach

DR. JAMES B. CONANT

Distinguished for his work in organic chemistry; president of Harvard University.

THE PROGRESS OF SCIENCE

THE HARVARD TERCENTENARY CONFERENCE OF ARTS AND SCIENCES

THE Harvard Tercentenary Conference of Arts and Sciences to be held in Cambridge from August 31 to September 12, the fortnight preceding the three-day celebration on September 16, 17 and 18, will be one of the most distinctive and important features of Harvard's tercentenary year It was decided more than two years ago that, although the festive and retrospective aspects of such an anniversary were not to be overlooked, the celebration should itself be primarily the occasion for a contribution to learning and a stimulus to scholarly achievement. So, before the concluding ceremonies bring to Cambridge a great concourse of the alumni and friends of Harvard, including some six hundred delegates from about four hundred and eighty universities, colleges, learned societies and other bodies concerned with higher education, about 2,500 American and Canadian scholars will gather to hear the papers and lectures to be given by seventy-three of the most distinguished men chosen from various fields of learning.

JOHN HARVARD
A STATUE BY DANIEL CHESTER FRENCH.

The process by which the contributors to the conference were chosen is itself significant. While the standard set was high, the selection was nothing so difficult or invidious as an attempt to make the final list a would-be official rating of the world's best scholars to the exclusion of others, on the assumption that they did not "rate" inclusion. Some five hundred names received consideration, divided with approximate equality among the "quadrants" of the Physical and Mathematical Sciences, the Biological Sciences, the Social Sciences and the Humanities—or Arts and Letters, to use a preferred designation. The final selection was controlled by two considerations: First came distinction and continued productivity, rather than eminence alone This test was applied to all. Second came special competence, to contribute to the three collaborative symposia on prearranged subjects thought to possess peculiar timeliness and importance These criteria are reflected in the program, which shows in the Physical and Mathematical Sciences, and to some extent in the Biological Sciences, a series of contributions embodying what happen to be the special interests of the individual contributor; while the rest of the program reveals an attempt to secure what is called "a common attack" by representatives of the Biological Sciences, the Social Sciences and Arts and Letters, upon problems of man in his relation to his fellows and to nature If, as it is hoped, the conference plan is itself a contribution to the strategy of man's search into the unknown, the hope is based upon the emphasis placed upon problems to be solved rather than upon one or more conventional disciplines as self-sufficient channels of approach.

Invitations to register as members of the conference were distributed widely among professors in the leading universities and colleges of the United States

Harvard College Library

THE EARLIEST CONTEMPORARY VIEW OF HARVARD COLLEGE, 1726

FROM AN ENGRAVING DRAWN BY WILLIAM BURGIS.

and Canada as well as among research institutes. The limits of space in the largest lecture halls have compelled a limitation of the membership to 2,500. Even with this limitation, overflow arrangements, with loud-speakers, will probably have to be made in adjoining halls, in the case of the collaborative symposia. Admission to lectures will be controlled by badges of different colors, each indicating one of the four "quadrants." Preference in admission will be given to those wearing the color corresponding to the subjects of the sessions. Associate membership will be granted to a limited number of applicants, to whom no assurance can be given that they can hear papers otherwise than by loud-speaker in a neighboring hall. Even at the few lectures designated as "public," the members of the conference will probably fill the lecture halls, thus forcing others to content themselves with the loud-speakers nearby or to resort to the radio—for the lectures likely to be of greater public interest will be broadcast by the Boston, non-profit, educational station W1XAL operating on short-wave frequencies of 6.04 megacycles (49.67 meters) or 11.79 megacycles (25.45 meters).

Nominally extending over the two weeks from August 31 to September 12, the program of the first week has chiefly to do with the Mathematical and Physical Sciences and is coordinated with sessions of the American Mathematical Society, the Mathematical Association of America and the American Astronomical Society. The second week begins with the only plenary session, at which addresses will be made by President James B. Conant and Jerome D. Greene, director of the tercentenary celebration and chairman of the executive committee of the conference, on September 7.

The conference will be opened with a lecture by Professor Ronald A. Fischer, professor of eugenics in the University of London, on "Uncertain Inference." This will initiate the symposium on the Mathematical and Physical Sciences.

The first collaborative symposium will be devoted to "Factors Determining Human Behavior," which will open on the morning of September 7 with a lecture by Dr. Edgar Douglas Adrian, Foulerton professor of the Royal Society in the field of physiology. An evening lecture, by Dr. Abbott Lawrence Lowell, emeritus president of Harvard University, on "An Example from the Evidence of History," in the afternoon will be followed by a late evening lecture by Dr. Bronislaw Malinowski, on "Culture as a Determinant of Behavior."

The second collaborative symposium, entitled "Authority and the Individual," will occupy two days. It will be divided into four parts, one entitled "The State and Economic Enterprise." Under this section on September 8 Dr. William E. Rappard, professor of public finance in the University of Geneva, will read a paper on "Economic Nationalism." The second section of this symposium is entitled "Stability and Social

Harvard Institute of Geographical Exploration

AERIAL VIEW OF HARVARD UNIVERSITY

SHOWING THE CHARLES RIVER AND BOATHOUSE IN THE FOREGROUND. THE HOUSES WHERE THE UPPER CLASSMEN LIVE FACE THE RIVER. IN THE REAR, UPPER CENTER, ARE THE CHAPEL, LIBRARY AND FRESHMAN DORMITORIES, IN THE HISTORIC COLLEGE YARD. THE COLLEGE WAS FOUNDED IN 1636, AND THE FIRST BUILDINGS WERE IN THE COLLEGE YARD.

Harvard Film Service

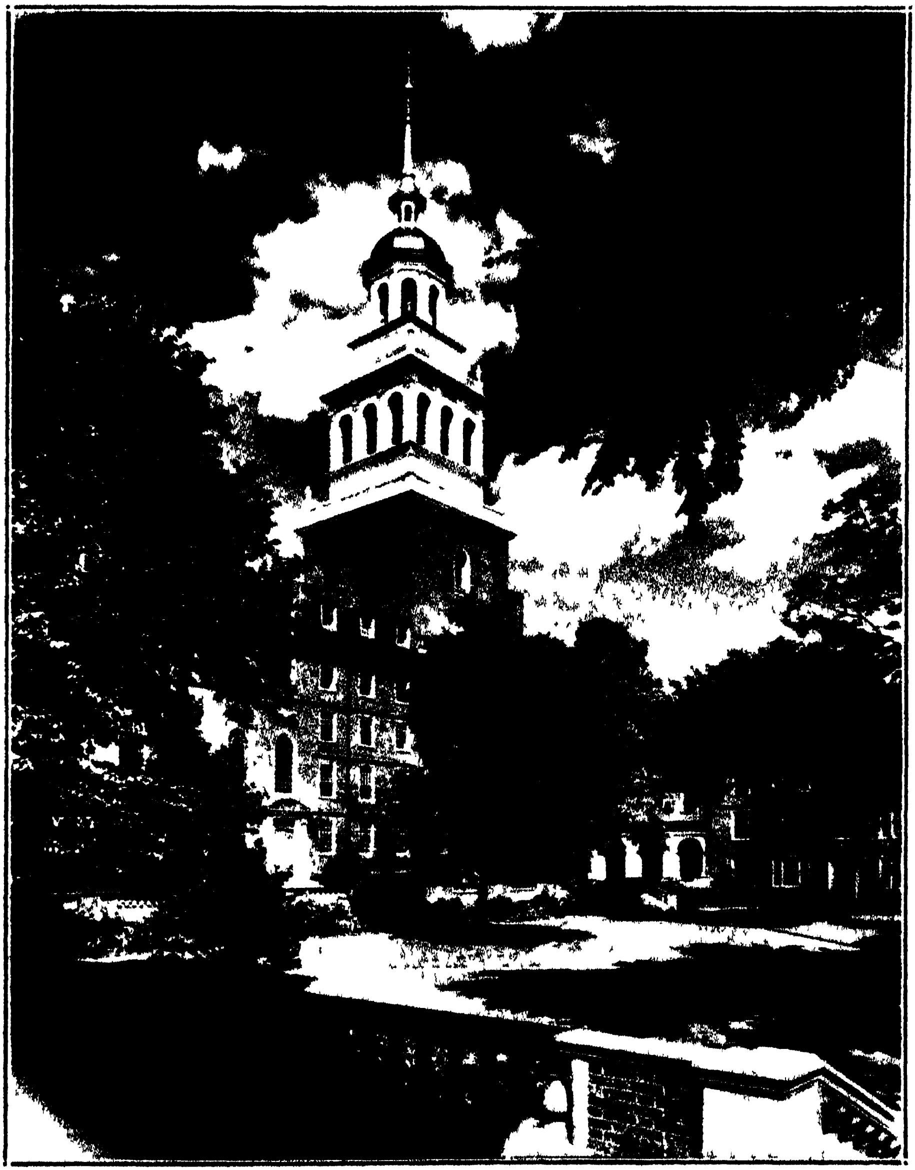
WIDENER LIBRARY OF HARVARD UNIVERSITY

CONTAINING 3,800,000 VOLUMES, MAKING IT THE LARGEST UNIVERSITY LIBRARY IN THE WORLD

Harvard Film Service

THE OLDEST COLLEGE BUILDING IN THE UNITED STATES

Massachusetts Hall of Harvard University, which was built in 1720. Once it was occupied by Colonial troops during the Revolutionary War; now it is used as a dormitory for freshmen.



Harvard Film Service

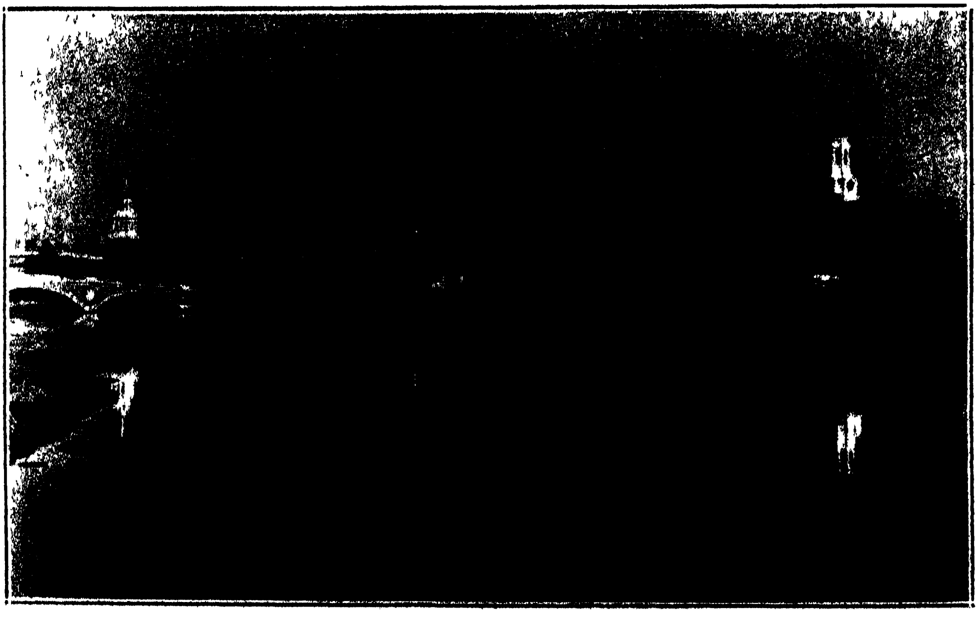
LOWELL HOUSE

ONE OF THE DORMITORIES FOR UPPER CLASSMEN.

Change." The main feature of the latter will be an evening lecture by Dr. John Dewey, professor of philosophy, emeritus, in Columbia University, on "Authority and Resistance to Social Change." The third sub-topic in this symposium is entitled "The Place and Functions of Authority." Taking part in this group of papers will be Corrado Gini, professor of statistics and sociology in the University of Rome. Arts and Letters is represented in the fourth section of this symposium on "Authority and the Individual," under the title "Classicism and Romanticism." An important feature of this part of the program is a lecture by Dr. E. J. Dent, professor of English in the University of Cambridge, on "The Historical Approach to Music." This lecture is, however, to be given on September 3.

The third collaborative symposium will bear the pregnant title, "Independence, Convergence and Borrowing in Institutions, Thought and Art." "Europe and the Near East" and "The Middle Ages" are the two divisions under this head. This symposium will be concluded by an evening lecture, entitled "Medieval Universalism and its Present Value," by Dr Étienne Gilson, who is professor of philosophy in the Collège de France. To readers of the SCIENTIFIC MONTHLY, possibly the symposia on the natural and exact sciences will be of even greater interest than the program outlined above. It will be divided into three parts, "Europe and the Near East," "The Middle Ages" and "East and West."

This symposium on the "Biological Sciences" will begin on September 8, and contains four divisions· The first is "Various Aspects of Biology" (under which are gathered miscellaneous papers by distinguished foreign and American men working in the biological sciences); "Experimental Morphology"; "Parasitism"; the final section of this symposium on the "Biological Sciences" will be entitled "The Applications of Physical Chemistry to Biology" Among the speakers in this group will be Dr. J. H. Northrop, a member of the Rocke-



STUDENT RESIDENCES ALONG THE CHARLES RIVER feller Institute, who will address the conference on "The Use of Isotopes as Indicators in Biological Research."

The fifth, the last of these collaborative symposiums, is one on the "Physical Sciences," which will have sections on "Mathematics," "Astrophysics," "Cosmogony," "Cosmic Radiation," "Nuclear Physics" and "Communication Engineering." The latter is by Dr. Frank B. Jewett, of the Bell Telephone Laboratories, whose picture was reproduced in the August issue of the SCIENTIFIC MONTHLY in connection with the award to him of the Franklin Medal of the Franklin Institute.

It is of special interest to note that the sessions on "Nuclear Physics," which are to be held on September 8 and 9, are made up entirely of American physicists.

The session on "Geology and Geophysics" will consist of a lecture by E. B Bailey, professor of geology in the University of Glasgow, and of contributions from American men of science.

The section of chemistry will have the following papers: by Peter Debye, professor of physics in the University of Leipzig, on "The Structure of Liquids", by Hans Fischer, professor of chemistry in the Technische Hochschule of Munich, on "Chlorophyll"; by Leopold Ruzicka, professor of chemistry in the Technische Hochschule of Zurich, on "The Male Sex Hormones."

Friedrich Bergius, of the Deutsche Bergin-Aktiengesellschaft in Heidelberg, will present the only paper in connection with the section on "Industrial Chemistry." His contribution is entitled "The Conversion of Wood into Carbohydrates and Technical Problems in the Industrial Use of Concentrated Hydrochloric Acid."

JEROME D. GREENE,
Director
HARVARD TERCENTENARY CELEBRATION

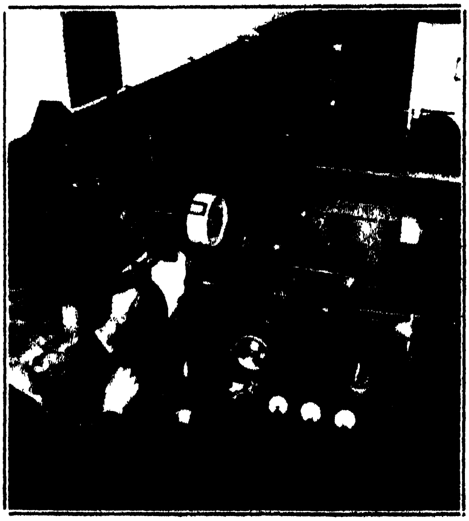
SUMMER CONFERENCES ON SPECTROSCOPY AND ITS APPLICATIONS, AND ON COLOR, AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

IN the present age of scientific specialization any cooperative effort which overlaps the arbitrary lines of demarcation between the sciences is of unusual interest. An example of this is the series of one-week conferences on spectroscopy held in the George Eastman Laboratories of the Massachusetts Institute of Technology during the past four summers. Biologists, chemists, physicists, astronomers, metallurgists, engineers, agricultural scientists, physicians and representatives of other branches of science and industry have met together in increasing numbers to discuss spectroscopy, particularly as applied to the analysis of materials.

The first conference, arranged in the summer of 1933 by Professor George R. Harrison, director of the research laboratory of experimental physics at the institute, attracted some seventy scientists from America and abroad. As knowledge of the applicability of spectrographic methods of analysis to various fields has grown, interest in the conferences has spread, with a resulting increase in enrolment from year to year, until at the conference just concluded over 200 were in attendance during the first three days, when this subject was under discussion An additional 200 persons registered at a conference on color held during the last three days of the week beginning on July 20. The program of the spectroscopy conference was in charge of Professor Harrison, while that of the color conference was under the chairmanship of Professor Arthur C. Hardy, of the physics department of the institute, president of the Optical Society of America.

SECTION OF THE TRACK FOR PLATE-HOLDERS

IN THE LARGE SPECTROSCOPIC ROOM OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY'S NEW SPECTROSCOPIC LABORATORY. THE DIAMETER OF THIS CIRCULAR TRACK IS TEN METERS.



MACHINE FOR MEASURING AND COMPUTING WAVE-LENGTHS

OF SPECTRUM LINES 20 TIMES FASTER THAN HAS HITHERTO BEEN POSSIBLE HAS BEEN DEVELOPED IN THE DEPARTMENT OF PHYSICS AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY BY PROFESSOR GEORGE R. HARRISON, DIRECTOR OF THE INSTITUTE'S SPECTROSCOPY LABORATORY.

Although a wide variety of subjects was covered at the spectroscopy conference, the meetings were noteworthy for the willingness of specialists in a given field to listen to papers presented by workers in other fields. Arguments between biologists on such things as the absorption spectra of haemoglobin derivatives were participated in wholeheartedly by physicists, chemists and others not particularly familiar with biological terms but having very definite ideas as to proper spectrographic procedure, with the result that numerous lively discussions featured the meetings.

On Monday morning a series of five half-hour papers on analysis of materials by means of the emission spectrum was given by W. F. Meggers, of the National Bureau of Standards, G. O. Langstroth, of McGill University; David Richardson, of the Massachusetts Institute of Technology; O S. Duffendack, of the University of Michigan, and Mary E Warga, of the University of Pittsburgh

The Monday afternoon session was devoted to biological spectroscopy, with papers by G. I. Lavin, of the Rockefeller Institute; L. H Flint, of the U. S. Department of Agriculture, J. S. Foster, of McGill University; and E S. Miller, of the University of Minnesota.

Tuesday morning was devoted to metallurgical spectroscopy, papers being given by J. S. Owens, of the Dow Chemical Company; D. J Crawford, of the Watertown Arsenal; R. A. Sawyer, of the University of Michigan; H. B. Vincent, of the same institution; and L. Strock, of Lucius Pitkin, Inc.

Biological spectroscopy was again taken up on Tuesday afternoon, papers being given by D. L. Drabkin, of the University of Pennsylvania; D. R. McRae, of McGill University; T. R. Hogness, of the University of Chicago; C. B. Coulter, of Columbia University; and L. E. Gaul, of New York City.

Absorption spectrophotometry was the subject of Wednesday morning's discussion, with papers by Professor Hogness; Brian O'Brien, of the University of Rochester; Egon Lorenz, of the U. S Public Health Service; Dr. Drabkin; and O. R. Wulf, of the U. S. Bureau of Chemistry and Soils.

General spectroscopy was discussed on Wednesday afternoon, three papers being read, by Dr. Meggers; H. A. Robinson, of the University of Uppsala; and Dr. O'Brien A two-hour general discussion of spectrographic methods concluded the spectroscopy conference.

Equal interest was shown in the color conference, papers being given by L. A. Jones, of the Eastman Kodak Company; John W. Forrest, of the Bausch and Lomb Optical Company; H E. Ives, of the Bell Telephone Laboratories; K. S Gibson, of the National Bureau of Standards; J. L. Michaelson, of the General Electric Company; G. F. A. Stutz, of the New Jersey Zinc Company; C. E. Foss, of the International Printing Ink Corporation; Lester C. Lewis, of the Mead Corporation, Selig Hecht, of Columbia University; Deane B. Judd, of the National Bureau of Standards; D. L MacAdam, of the Eastman Kodak Company; F. W. Sears, of the Massachusetts Institute of Technology; H. P. Gage, of the Corning Glass Works; Walter M. Scott, of Gustavus J. Esselen, Inc.; Dorothy Nickerson, of the U. S. Bureau of Agricultural Economics; F. H. Norton, of the Massachusetts Institute of Technology, K S Gibson, of the National Bureau of Standards, A. W. Kenney, of E. I. du Pont de Nemours and Company; M. Rea Paul, of National Lead Company; W. D. Appel, of the National Bureau of Standards; I. H. Godlove and R. E Rose, of the du Pont Company

Registration at both conferences was free and open to any one interested in the subjects under discussion. A similar conference or group of conferences is being planned for next summer.

UTILIZATION OF THE WHOLE COTTON PLANT

At the second Dearborn conference of the Farm Chemurgic Council, Dr. Frank K. Cameron, of the University of North Carolina, read a paper describing the work of his students on "Whole Cotton as a Source of Oil and Alpha Cellulose."

CUTTING COTTON WITH A MOWING MACHINE

BALING THE WHOLE COTTON PLANT

Several years ago, when the over-supply of lint cotton became a matter of concern, the investigators became interested in the possibilities of growing cotton as a source of cellulose. If the cotton plant could be developed into such a source it would be of considerable benefit to the southeastern states, which are at a disadvantage in competition with the southwestern states in the growing of lint cotton. The prospect of a new outlet for the chief money crop of this region, without radical changes in the present farm practice, was a primary incentive to the series of investigations carried on since 1929.

The growing experiments have been made by N. W. Dockery near Rockingham, N. C. Crowding and starving the plant forced it to mature early and give a larger proportion of lint cotton than does the normal plant. The crowding also caused the great majority of the bolls to ripen at the same time. The plants reach a maximum cellulose content of about 50 per cent. about 25 weeks after planting. The plants are cut with a mowing machine and immediately baled in the field. This baled material may be stored without deterioration. Some bales have stood in the open without injury for five years. It has been found essential that the material be stored under conditions which will prevent the accumulation of inorganic dust.

The baled material is comminuted to a uniformly ground mass of fluffy nature (because of the large proportion of lint cotton). An ordinary agricultural type of hammer mill serves the purpose admirably. Thus a material is obtained which is in a much more favorable condition for pulping than the usual wood chips The oil is extracted by solvents and an oil similar to cottonseed oil and a wax similar to beeswax recovered. The residue has, to date, been made into a pulp by two methods. The two processes studied are, first, the nitric acid process and, second, the alkali process. The resulting pulp is suitable for the manufacture of many cellulose products. Further growing experiments are under way and it is planned to continue the investigation on pulping by a study of the other commercial methods as soon as equipment and funds are available.

ALFRED R. MACORMAC

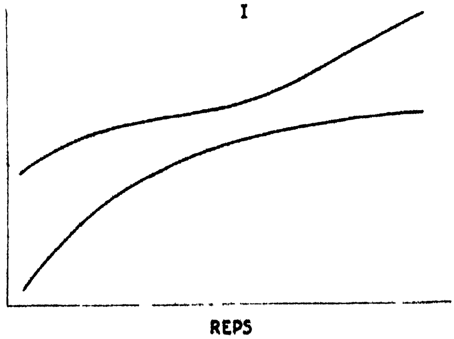
125-POUND BALE OF WHOLE COTTON PLANT COMPARED WITH 500-POUND BALE OF LINT COTTON

THE ROLE OF TIME IN THE LEARNING PROCESS

THE writer has recently succeeded in isolating a process of mental growth which may require a complete reordering of the present-day conceptions of human learning.[1] In essence, the findings rest upon the use of an experimental device which reduces the adult subject to a beginning point only slightly above that of a child. From this low point the growth called learning is charted on its upward rise and is found to present two distinct, even opposed processes. The earlier or primary growth seems to require a new frame of thought and a new logic, while the later, secondary process is in complete accord with our present conceptions.

The experimental technique employed in these studies involves a mirror-vision coordination where the subject traces the outline of a path by means of a mental stylus as the path is revealed by mirror-vision only. The scores begin at a point very close to zero, and the experimental controls at every stage of the learning are very satisfactory.

An indication of the opposed character of the two growth processes is seen in the following· Primary growth is early, secondary is late; individual differences are decreasing in primary growth and increasing in secondary growth; primary growth is a positive function of the length of time interpolated between stimulations; secondary growth rests upon stimulation alone; primary growth is permanent, since time only enhances it, while secondary growth is temporary and requires constant stimulation. Fig. 1, showing the growth processes for a high and low efficiency group, presents the general character of the two growths. As time is interpolated the removal of individual differences at the left is greatly increased. As time is withdrawn, *i.e.*, stimulation increased, the point of greatest constriction moves to the left and falls to a lower point on the graph.



A DIAGRAMMATIC PRESENTATION OF THE EFFICIENCY SCORES (V) OF A VERY SUPERIOR AND AN INFERIOR GROUP PLOTTED AGAINST THE NUMBER OF REPETITIONS.

An indication of the havoc wrought in learning theory by the discovery of the primary growth process can be seen in its bearing upon the conception that learning is a selection of random movements. Keep in mind that the reduction of individual differences through this growth is supported by a correlation of .97 ± .002 in a study of 400 adult subjects. The poorer the subject the more he gains, which means that those with many good movements do not gain in proportion to the number of good movements, random or otherwise, since the greater gain is always on the side of the excess of poor movements. The growth rate in the primary process resembles the reduction of volume in a gas brought about by adding weights to the piston: the more disperse the gas, the greater the change.

An indication of the effect of interpolated time on early growth is shown in Fig. 2. The group with the time intervals, though initially inferior, rises to a level far above that of the continuous-practice subjects. The reliability ranges from statistical certainty at the second

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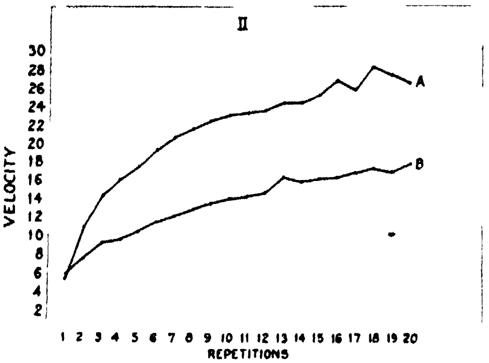
[1] Geo. S. Snoddy, "Evidence for Two Opposed Processes in Mental Growth," The Science Press Printing Company, Lancaster, Pa, 1935.



Early efficiency scores (V) of two groups under different conditions of practice. In group A repetitions were separated by 24-hour time intervals and in group B practice was continuous. Late in the learning these two groups are reversed, the continuous practice being superior.

repetition to four times this value at the twelfth repetition. Also the continuous-practice group becomes very much more variable as practice continues than is the case with the time-interval group; the stimulation is depressing the poorer members in the group with continuous practice and is increasing their variability. These subjects give every evidence of undergoing punishment. In the time-interval group the situation is reversed: the whole group is not only improving at a higher rate, but the lower subjects are profiting greatly from the time, and individual differences are being reduced. This seems to point unmistakably to the fact that primary growth is stabilization, not selection. A process of contraction is taking place in the individual subject, which is analogous to what takes place in the group or to what occurs in a sand pile when it settles. The survival-of-the-fittest origin of the selection theory gives us no reason to suppose it could explain what actually occurs in learning.

Other experimental devices show the same sequence of opposed growth processes when we are able to get the lowest level of growth under observation. The pursuit rotor has just given one of our research students exactly the same findings as I have indicated above. There is no reason to suspect that the peculiar character of our findings depends upon any other factor than the measuring of a level of mental growth which comes earlier than any we have studied heretofore.

Geo S. Snoddy
Indiana University

THE SCIENTIFIC MONTHLY

OCTOBER, 1936

THE PHYSIOLOGY OF LIFE AT HIGH ALTITUDES

THE INTERNATIONAL HIGH ALTITUDE EXPEDITION TO CHILE, 1935

By Dr. ANCEL KEYS

ORGANIZER AND MANAGER OF THE EXPEDITION, ASSISTANT PROFESSOR OF BIOCHEMISTRY,
THE MAYO FOUNDATION FOR MEDICAL RESEARCH

As one rises above the level of the sea, the pressure of the atmosphere (barometric pressure) falls; at 18,000 feet it is only about half as great as at sea level The *composition* of the air, however, does not change appreciably and air is about 21 per cent. oxygen at all levels. This means that, at 18,000 feet, a given breath of air will only supply half as much oxygen as at sea level, a difference which must be expected to have profound effects on men and animals which require oxygen for life. Fig. 2 shows the relation between altitude and air (and oxygen) pressure, and gives a few high altitude landmarks

In the early decades of the sixteenth century the Spanish Conquistadors invaded and despoiled the kingdom of the Incas. From the high plateaux of Peru and Bolivia they sent back tales of a fearful poison in the air of these mountains and of a dread disease, the "*sickness of the Andes,*" or "soroche,"[1] which no physician could cure. Breathlessness had long been known in certain cantons in Switzerland, but people in Europe did not experience sensations comparable to those of the South American explorers until the first attempts to climb Mt. Blanc (eighteenth century).

Scientific interest in the problems of life at high altitudes might well have begun with Lavoisier's demonstrations of the rôle of oxygen in the maintenance of life (latter part of the eighteenth century). However, aside from murdering a few mice in evacuated bell jars, little was done until balloon ascents captured attention seventy years ago. The French physiologist, Paul Bert, attempted to bring high altitude into the laboratory by studying men in vacuum chambers. Other investigators argued that, since the effect of low air pressure seems to be primarily owing to reduced oxygen pressure, high altitude can be simulated at sea level pressure by replacing some of the oxygen in the air by the inert gas nitrogen. Both types of chambers are still being used, but the abnormality of life in such chambers makes them of limited utility except for acute experiments. The immediate results of sudden reduc-

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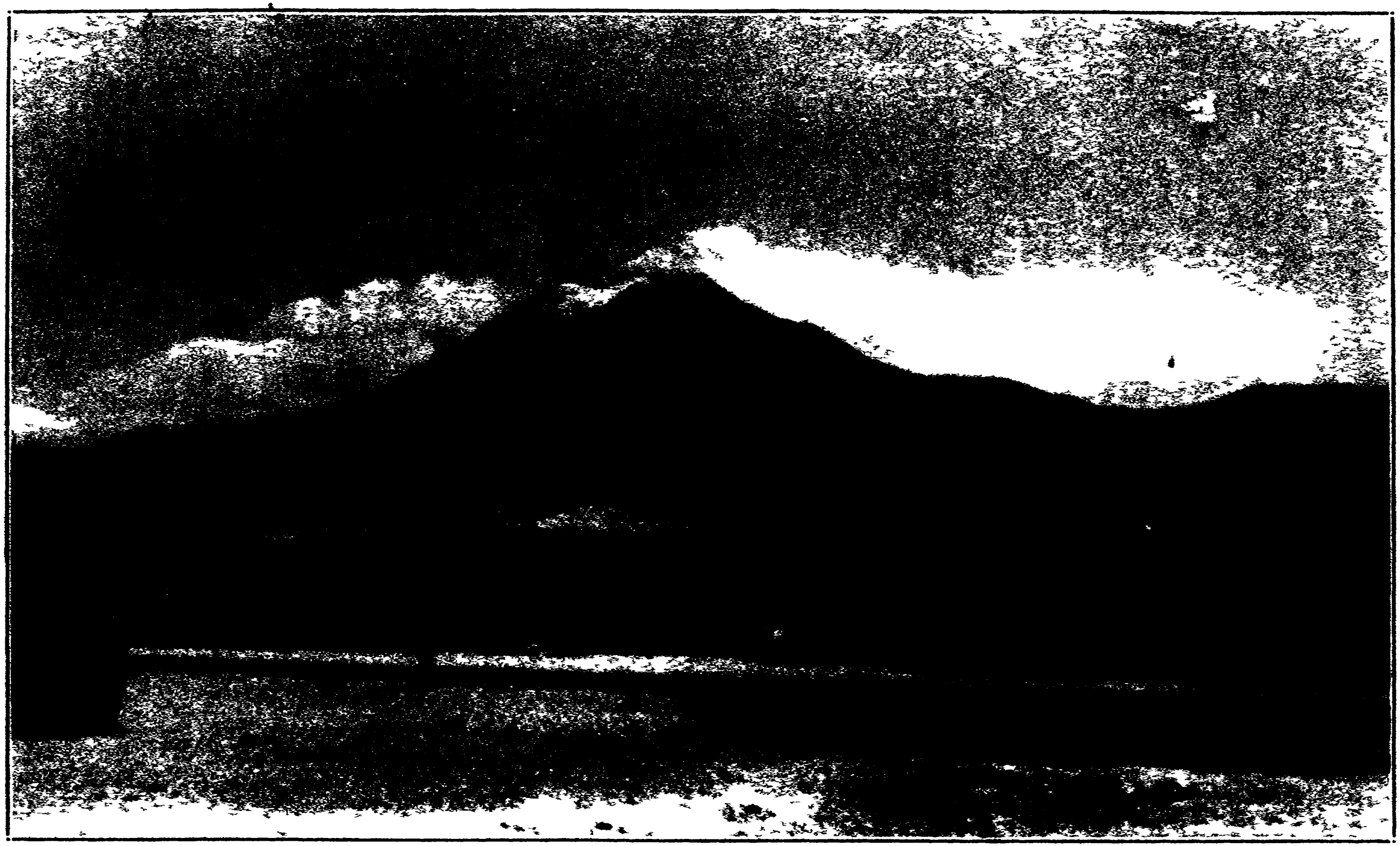
[1] The Quechua word "soroche" has gained some currency owing to the prevalence of the condition in the Andes and because for several centuries it was thought, in Europe at least, that severe mountain sickness is peculiar to the highlands of South America. In parts of Chile and Bolivia the term "puna" is used.



CERRO DE AUCANQUILCHA FROM THE VILLAGE OF OLLAGÜE

THE ALTITUDES OF THE THREE PEAKS VISIBLE ARE, FROM LEFT TO RIGHT, 20,150, 20,280 AND 20,100 FEET SEE PHOTOGRAPH ON PAGE 306 FOR APPEARANCE OF THE LEFT AND CENTER PEAKS AS SEEN FROM THE RIGHT PEAK.

tion in air pressure are relatively easy to explain; the restoration of physical and mental vigor after some time at high altitude and the delayed onset of altitude sickness are both more interesting and less intelligible

In these days there should be no need to dwell on reasons for making a study of the adaptation to life at high altitudes.

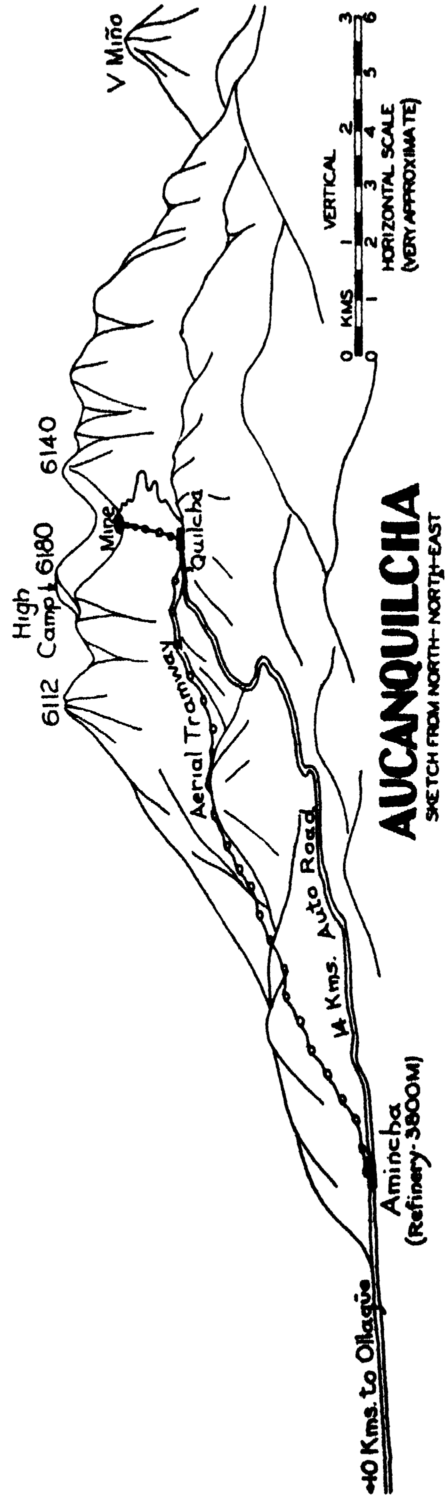


FIG. 1.

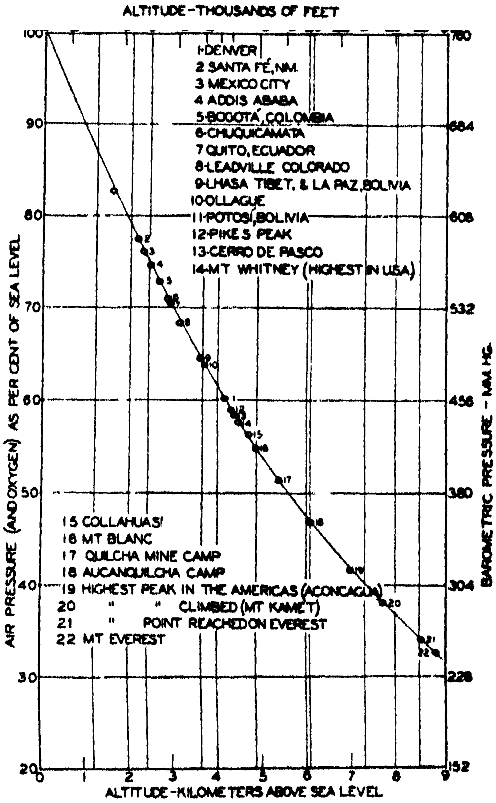


FIG. 2.

THE RELATION BETWEEN AIR (AND OXYGEN) PRESSURE AND ALTITUDE. THE NUMBERED POINTS ALONG THE CURVED LINE REFER TO THE VARIOUS PLACES TABULATED.

Each day brings new stories of high flying records, stratosphere balloons and plans for commercial transportation in the sub-stratosphere. Prospectors are finding more mineral deposits to be exploited in high mountains As this article is being written, the latest Mount

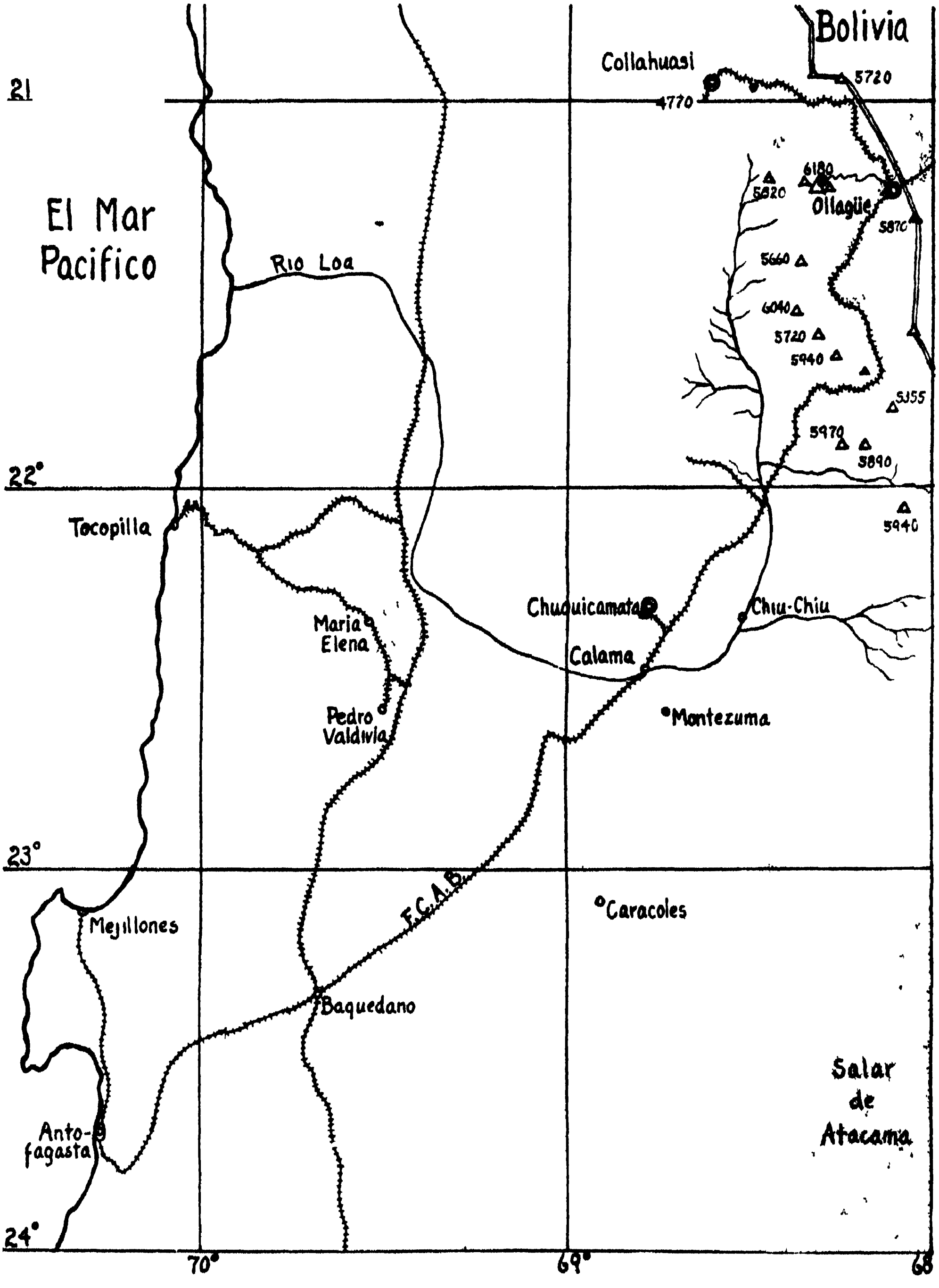


FIG 3.

Map of the region in Northern Chile in which the International High Altitude Expedition worked in 1935.

Everest Expedition is preparing its base camp for another great effort which the world will follow with sympathetic interest. In all these enterprises the low air pressure of high altitude, with the corresponding lack of oxygen, is a major hazard.

In the civilized world it is now agreed that the physiological peculiarities of life at high altitude result almost entirely from the diminished oxygen pressure in the air. At high altitude one also finds intense cold and very great radiation from the sun, especially of ultraviolet light, but these are only small modifying factors; one can easily develop plenty of mountain sickness in a warm house at high altitude.

The association of mountain sickness or soroche with a definite geographical place is easily understood. It is common in the Himalayas and in the Andes to be told that certain regions "contain much mountain sickness," or that, of two high peaks or passes of similar height, one "has much more soroche" than the other. In some cases there may be sound reasons for these statements, but the causes seem to be simply in differences in the terrain—that is, in the muscular exertion required to travel or in the speed with which altitude may be gained. For example, the Andes have an unenviable but merited reputation for producing more "soroche" than equally high regions elsewhere; the cause is probably that in the Andes one often ascends rapidly from the lowland to great heights.

Visitors to Pike's Peak know that the trip from 6,000 to 14,008 feet in a few hours is apt to leave one gasping and gazing about with "dull and jaundiced eye," and that a stay overnight is often attended with severe headache, sleeplessness and, not rarely, nausea. Many feel little at first but fall ill after a few hours, some never suffer anything worse than breathlessness, while the caretakers of the inn seem to be quite normal unless they attempt strenuous exercise These differences illustrate two of the most interesting questions about high altitude effects, individual differences and acclimatization.

THE EXPEDITION TRAIN AT OLLAGÜE.

NOTE STEPS UP TO THE LABORATORY CARS

It is well known that many otherwise

BOLIVIAN TYPES

PREDOMINATE IN THE MOUNTAIN REGION OF NORTHERN CHILE NEAR THE BOLIVIAN FRONTIER. THE WHITE HAT AND SHAWL ARE CHARACTERISTIC.

healthy people are unable to stand high altitude and that as one approaches really great heights individual differences are accentuated. Moreover, aside from the recognition that people with definite cardiac or respiratory weakness are unfitted to go high, attempts to predict the responses of individuals to life at high altitudes heretofore have been attended with little or no success.[2] All these points were very clear on our expedition to Chile.

Mountaineering parties and explorers have demonstrated that by acclimatization man is able to live and to work at altitudes where continued existence otherwise would be impossible. The summer vacationer who spends a few days or weeks at eight or ten thousand feet considers himself rather hardy, but large communities at these altitudes are not rare. The mountaineer who, purple and gasping, drags himself to the top of a major peak in the Alps does not always remember that there are thousands of people in Asia and in South America who make their homes and carry out their daily work at an equal altitude. The aviator flying to above 20,000 feet without an artificial supply of oxygen suffers anything from mild malaise and lack of coordination to complete mental and physical collapse;[3] at the same and higher altitude the acclimatized mountaineer may feel almost entirely normal at rest and is able to do arduous physical work for hours with only moderate discomfort.

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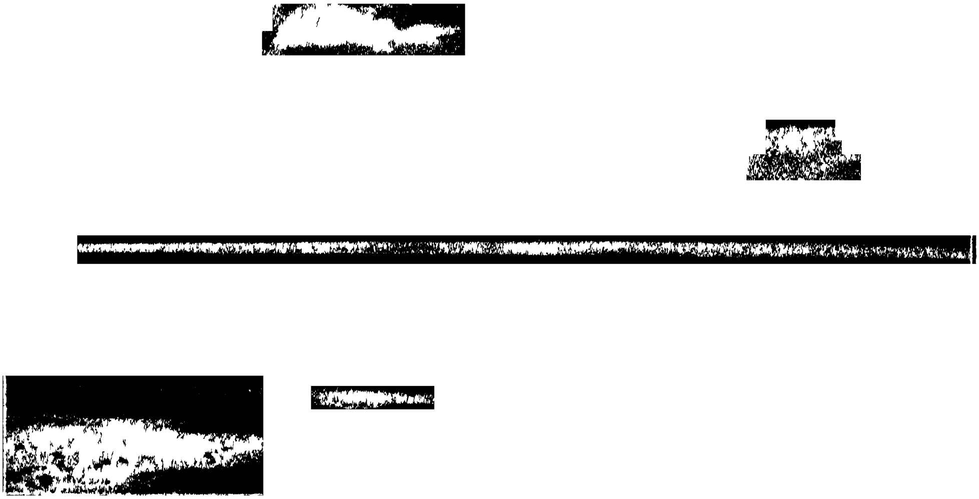
[2] Predictions as to ability to *fly* high for a *short time* are often relatively accurate.

[3] Physical exertion intensifies the danger but, even when sitting quietly, loss of consciousness followed by death can result, especially above 23,000 feet. Only good luck allowed Tissandier to return alive from the balloon flight in 1875 on which his two companions died at a little over 25,000 feet.

Knowledge of physiology and physiological theory would predict the general nature though not the precise form of the discomfort and danger of rarefied air, but gives very little clue to the acclimatization process. In this respect there are similarities with chronic heart disease[4] in which also physiology can tell why the patient is incapacitated but not why, in many cases, "compensation" is accomplished so that the sufferer is able to lead a nearly normal life. Perhaps the resemblance is more than superficial, in both cardiac disease and high altitude, deficiency of oxygen in the blood (anoxemia) is responsible for most of the unpleasant symptoms

It will be agreed, then, that the problem of acclimatization to life at high altitude is of much theoretical and practical interest. For this reason low-pressure and low-oxygen chambers have been built in England, Denmark, Germany and the United States, laboratories have been established in Switzerland and Italy and special expeditions have gone to the Alps, to Pike's Peak, to Madeira, to the Caucasus and to Peru. Physiologists have turned mountaineers and have made innumerable experiments on themselves. These researches have not been unfruitful, but they have further emphasized the interest of the problems and the incompleteness of our knowledge.[5]

In the first place, it is clear that man at high altitude needs as much oxygen as at sea level and that when he exerts his muscles the necessary increase in oxygen consumption is about the same in both cases. Primary interest has centered in the means whereby a normal amount of



THE SALAR DE OLLAGÜE

NEAR THE GREAT SALAR DE UYUNI. ALTITUDE 12,000 FEET.

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[4] Including the various forms of cardiac insufficiency but not conditions like angina pectoris

[5] The history of the earlier work can not be summarized here, for an introduction refer to Joseph Barcroft, "Lessons from High Altitudes," 1926, Cambridge; A. Loewy, "Physiologie des Hohenklimas," 1932, Berlin; J. S. Haldane, "Respiration," 1935, New Haven.

oxygen is extracted from an oxygen-poor environment and is carried to the tissues of the body. A second set of questions is concerned with the ability to perform physical and mental work at high altitudes. Finally, we ask what differentiates the unacclimatized from the acclimatized man and what determines the extent of acclimatization possible to a given man.

Early in 1934 it was decided to make a new and more ambitious attack on these problems The earlier work had shown that a stay of at least several months in the field should be provided for if true acclimatization was to be developed in the members of the expedition who were to be the principal experimental subjects. It was agreed that really great heights should be attained because the phenomena of adjustment are most remarkable above 15,000 feet. The most hopeful lines of attack seemed to be to concentrate on the chemistry of the blood and its ability to carry oxygen, on the performance of the heart and lungs, and on the responses of the body to various standard physical and mental tasks.

These considerations guided the organization of the International High Altitude Expedition A relatively large party of robust investigators was needed to provide the varieties of technical knowledge, as well as the number of skilled analysts, required for the complex experiments planned. With the help of Professors L. J. Henderson, Sir Joseph Barcroft and August Krogh the personnel of the expedition was enlisted from the faculties of the universities of Harvard, Copenhagen, Cambridge, Duke, Columbia and Chicago; the ten men chosen embraced the fields of physiology, biochemistry, zoology, medicine and psychology.[6] Financial support was guaranteed by the universities and various research foundations and societies.[7]

Our program called for precise experiments and analytical procedures only possible with elaborate apparatus. Moreover, we wished to reduce to a minimum extraneous factors of discomfort which might tend to confuse our results High altitude locations suitable to our needs are not numerous and are confined to two regions: Central Asia and the Andes of South America between about 10° and 30° S latitude. We finally selected the Chilean Andes on the Bolivian frontier near the line of the Antofagasta-Bolivia Railroad. The region is shown on the map (Fig 3).

A period of some months was occupied at the Fatigue Laboratory with assembling equipment and making a thorough study of the members of the expedition at sea level. The first half of the expedition sailed from New York on March 22, 1935, arriving at Antofagasta on April 7, and proceeding to Calama and Chuquicamata the next day. Two weeks later Matthews arrived from England and the last four members of the expedition arrived in Chile on May 18. Table I shows the itinerary in Chile.

By the newcomer, breathlessness may be scarcely noticed at Calama, but at Chuquicamata (9,200 feet) it is much more marked, though there is only a dif-

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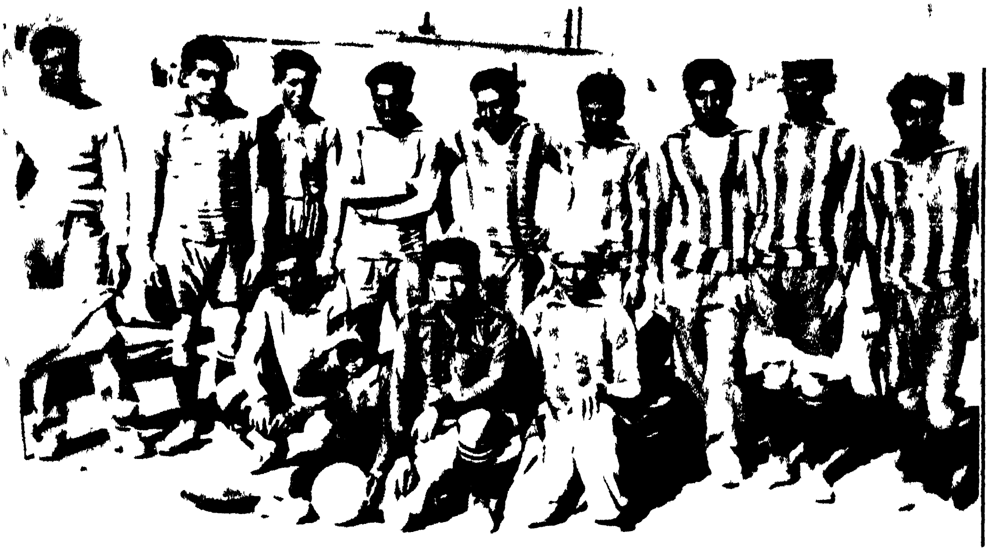
[6] In addition to the writer, the party consisted of: Drs E. S. Guzman Barron, E. Hohwü Christensen, David Bruce Dill, H. T Edwards, W. H. Forbes, F. G. Hall, Ross A. McFarland, Bryan H. C. Matthews, John H. Talbott.

[7] The expedition was supported by grants from the Fatigue Laboratory and the Milton Fund, Harvard; Duke University; Copenhagen University; King's College, Cambridge University; Columbia University; the National Research Council; the Royal Society, London; the Corn Industries Research Foundation; the Rask-Ørsted Fund and the Carlsberg Foundation, Copenhagen; the Josiah Macy Foundation and the American Association for the Advancement of Science. We are also much indebted to the Chile Exploration Company and its officers in New York and in Chile, to Señores Hipolito and Juan Carrasco of the S. I A. M. Carrasco, to Messrs. Packard and Bell, of the Poderosa Mining Company, to the Ferro-Carril de Antofagasta a Bolivia, and to the many people, officials and private citizens who facilitated our work in Chile.



FOOTBALL AT HIGH ALTITUDES

THE TEAMS FROM THE SULFUR MINES MEET AT OLLAGUE (12,020 FEET) TEAM FROM THE 'QUILCHA CAMP (17,400 FEET)

FOOTBALL TEAM FROM THE SANTA ROSA MINE CAMP (16,400 FEET).

TABLE I
EXPERIMENTAL STATIONS ESTABLISHED BY THE INTERNATIONAL HIGH ALTITUDE EXPEDITION

Station	Period of occupation	Corrected barometric pressure	Altitude	
		mm mercury	meters	feet
Chuquicamata	April 8 to June 4	543	2,810	9,200
Ollagüe	June 5 to June 13 and June 25 to July 18	489	3,660	12,020
Collahuasi (Montt) . . .	June 13 to June 25	429	4,700	15,140
Aucanquilcha .	June 26 to July 15	401	5,340	17,500
Punta de Cerro . .	June 29 to July 14	350	6,140	20,140
Last departures from Chile August 17				

ference of about 1,500 feet in altitude. The large physiological effect of relatively small change in altitude is increasingly noticeable above about 7,000 feet and could be roughly predicted from the known chemical properties of the blood.

Chuquicamata, the world's greatest copper camp, was to be our base of operations in the field. The generosity of the Chile Exploration Company and the friendly helpfulness of the residents there not only facilitated our work but made us comfortably at home. Our work at Chuquicamata was partly concerned with organization of our field laboratory and preparations for the higher stations and partly with experiments and observations. With the generous help of Mr. Arthur Heskett and other officials of the railroad, four railway cars were outfitted for the field work, a sleeping car, a kitchen car and two laboratories. Our gasoline generator provided electric light for the laboratory cars and current for

LLAMA (LEFT) AND VICUÑA
AT CHUQUICAMATA (9,200 FEET). DR. HALL IS WEARING A CHILEAN INDIAN SHAWL.

GOING UP ABOUT 17,000 FEET.

NOTE DETRITUS OF SEVERE FROST ACTION BUT ABSENCE OF EROSION

the centrifuge. Four servants and helpers were engaged, who were not dismayed at the prospect of "puna, carne duro y mucho frio" (mountain sickness, coarse food and great cold).

The altitude has little outward effect on the life of the 18,000 inhabitants of Chuquicamata. In addition to breathlessness, newcomers may suffer from mild headache for a day or two and may be restless at night, but these effects soon disappear. Football and boxing are enthusiastically played by the workers, while golf, and to a smaller extent volley ball and tennis, are popular with the staff, which is largely composed of North Americans. Both groups frequently hold dances where the tempo is by no means slow nor does fatigue cause them to stop early.

Both workmen and staff form a permanent population at Chuquicamata, and many people there have records of residence as long as twenty years and more. The staff members return home for several months every few years and make fairly frequent visits to the coastal towns of Antofagasta and Tocopilla. The workmen, however, rarely make visits to the lowland. In the case of the staff, the loneliness and desolation of the surroundings and lack of diversion are probably more compelling reasons than altitude for return to the lowland, *i.e.*, the reasons are more psychological than physiological, but it is not improbable that the undercurrent physiological effects have some bearing on the general state of mind.

At this altitude acclimatization is very rapid, most of the adjustment in our group being accomplished in less than a week, but we could see further improvement for several weeks. Even with complete acclimatization, however, it must be realized that in some respects man is definitely physically inferior at this altitude as compared with sea level The frequent sight of workmen running home a mile or more is impressive chiefly because it is surprising that they retain so large a fraction of their sea-level ability. As would be predicted from physiological considerations, the effects of altitude become prominent in work of great intensity such as can be maintained only for a period of some minutes; moderately hard work is little more tiring than at sea level. Mental and sensory functions are not affected [8]

Aside from the expected increase in concentration of red cells in the blood we could find no characteristic results of long residence at Chuquicamata. The large hospital, which receives cases from many miles around, is admirably run and keeps excellent records. From consultations with the chief of the hospital, Dr Pablo Schlack, and his assistants it was learned that the course and incidence of disease is generally similar to the lowland Not only is the incidence of pneumonia not abnormal, but recovery does not seem to be hindered by the altitude. Infant mortality is lower than in many lowland communities in Chile, and maternal mortality is not high by North American and European standards.

At Chuquicamata we began to assemble our small zoo of experimental animals which, under the watchful eye of Dr. Hall, accompanied us later to all except the highest camp. As representative lowland animals we took rabbits, ducks and a sheep; for highland animals we had a llama, a pair of viscachas (*Lagostomus* species, large rodents native to the Andes), and the pet of the expedition, a tame, half-grown vicuña (*Lama huanachus glama*). Later we added a pair of Andean geese ("huallatas," *Chloëphaga melanoptera*) and a Bolivian ostrich or rhea (*Rhea americana*). These animals were housed in a special section of one of the laboratory cars when our train left Chuquicamata for Ollagüe on June 5.

Ollagüe (12,020 feet) is on an arm of the great "puna" (high plain) of southwestern Bolivia. Dozens of peaks, 18,000 to more than 20,000 feet high, cut off the horizon in most directions Close to the tops of many of these mountains in this volcanic region occur great deposits of native sulfur, the mining of which carries man to greater heights of permanent occupation than anywhere else in the world.

Ollagüe is the center of life for many miles around. Its 900 inhabitants are mostly of mixed Quechua Indian stock who, like their ancestors for untold generations, have rarely or ever been below 10,000 feet The Quechuas, with the anthropologically distinct Aymaras, who are rare in this region, divided the highlands between them long before the Incas came. Many local customs are still preserved, but the influence of the energetic Chileans, who are increasing in numbers in this region, is gradually making itself felt.

The broad and glaring plaza of Ollagüe is the meeting ground for the rival football teams from the nearby mines. The games are not very fast by sea-level standards, but offer remarkable testimony to the power of acclimatization to counteract the paralyzing effect of the thin air. One is reminded of the fact that polo apparently originated in a not dissimilar environment in Baltistan and Ladakh, where every village still has its polo field.

At Ollagüe Drs Talbott and Barron discovered two cases of "Monge's disease," a chronic form of mountain sickness recently described by Dr. Carlos Monge of Lima, in which the sufferers, chiefly adult natives of the highlands, complain of a chronic throat irritation, loss of appetite, nausea, muscular weak-

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[8] The detailed psychological findings for all the stations are being published in the appropriate technical journals by Dr. Ross A. McFarland.

'QUILCHA MINE CAMP (17,400 FEET).

LIVING QUARTERS OF THE WORKMEN SHOW AS A LINE IN THE LOWER FOREGROUND. THE LIGHT COLOR IS MOSTLY SULFUR ORE DUST, MIXED WITH OLD SNOW IN THE UPPER THIRD OF THE PHOTOGRAPH. THE MAIN PEAKS ARE TO THE LEFT OF THE PICTURE.

ness and pain, dyspnea (panting) and feeling of suffocation and anxiety. Such persons, like those suffering from acute or transient mountain sickness, quickly lose all symptoms when brought to a low altitude, but at high altitude the condition is refractory to medical treatment.

At Ollagüe for a day or two several members of the expedition had mild cases of mountain sickness and others slept poorly, but laboratory work went on. Within a week seven members had climbed to more than 18,000 feet on Volcano Ollagüe and two had climbed to the top of Aucanquilcha (20,280 feet), where we planned to establish an experimental station later.

From Ollagüe a spur line of the railroad winds northward for fifty miles up rolling hills to Collahuasi and the Poderosa and Miño Grande mines, attaining an altitude of 15,650 feet at the summit, Punta Alta.[9] Before they were shut down in 1930 these mines supported a population of several thousand people, which probably represented the largest population at such extreme altitude of which there is record. The usable railroad now ends 200 feet lower at Montt, where the expedition remained for two weeks. This is considerably above the highest point at which detailed observations had been made previously and our time was occupied by intensive experimentation.

Again, several members of the expedition were incapacitated for a short time, but each day brought increasing acclimatization. A Sunday excursion with Messrs. Packard and Bell, the English managers of the property, to the source of the Rio Loa at 12,000 feet, was a real holiday, including a swimming party in a warm pool and harmonica concerts uninterrupted by breathlessness.[10]

At Collahuasi Mr. Edwards arranged a hill climb in which three subjects exerted themselves to the absolute limit. He had been studying lactic acid, which normally accumulates in the blood when one gets out of breath from hard work. Many investigators had thought that the lactic acid causes or at least is necessarily related to the exhaustion of intense exercise. From our experiments on the stationary bicycle, however, we had been surprised to find that with increasing altitude there was a relatively decreased production of lactic acid in exhausting work. These results were confirmed by the hill climb and by later climbing and bicycle experiments at still higher altitudes.[11]

The expedition train returned to Ollagüe, where it was to be the base laboratory for the highest work. The sketch of Mount Aucanquilcha shows the relations between Ollagüe, the 'Quilcha Mine camp, the mine and our highest camp. From Ollagüe the Carrasco Mine Camp, 'Quilcha, can be reached by motor cars (with special low gears and cut-down cylinder heads) in an hour and a half. About 150 people live here at 17,500 feet, with the distinction of forming what is probably the highest permanent community in the world, and the camp merits special attention for this reason. The camp stands on a shelf several hundred yards wide on the northeast side of the mountain directly below the mine (Fig. 1). Water is carted up from lower springs.

The mine itself is at the extreme height of nearly 19,000 feet. The ore is brought down by a series of aerial tramways. The miners, however, go up to and down from the mine on foot, the climb being made in about an hour and a half and the return in about 25 minutes. Work is continuous throughout the year, except for brief periods during storms.

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[9] Slightly higher than Ticlio, Peru, often considered the highest point in the world to which rail has been laid.

[10] Later, at 20,140 feet on Auconquilcha, Matthews entertained the writer on the harmonica for six nights, eloquent testimony to the power of acclimatization.

[11] The results and discussion are being published by Mr. H. T. Edwards in the *American Journal of Physiology*.

MULE BACK AT 'QUILCHA.

MULES CAN BE RIDDEN TO 18,800 FEET.

Mining materials are carried up by mules (horses can not stand the altitude), but large pieces of equipment are carried on the shoulders of a dozen or more men who require an entire day for one trip of this sort In general, the miners regulate their own working hours Usually they start the climb to the mine shortly before 8·00 A.M and start down again towards 4.00 P.M ; the luncheon pause is brief. The work at the mine is mainly rather heavy manual labor, but the tempo is slow. The experienced miners know their capacity and it is rare to see acute shortness of breath.

A number of the miners have their families also at 'Quilcha. Stone huts provide primitive but effective shelter against the bitter wind and cold. The life, though hard, is not unbearable, and many people have been there for years. The labor turnover is high but not so high as casual inspection of the figures would indicate. Many of the miners quit work every six months or so but return from below (some of them go down to sea level) when their savings are exhausted. Among newcomers to the mine there is a very high turnover, because many of these men (most of them long accustomed to life at 12,000 feet) quickly discover that they can not become adjusted to the higher altitude. High wages bring a continual stream of job-seekers. The main population at 'Quilcha represents a group highly selected with respect to their ability to withstand the altitude.

We were surprised to learn that many of the best "old-timers" at the mine are Chileans, born and bred near sea level. The Andean peoples are by no means immune to "soroche" or "puna," and many lowland people are able to compete with them successfully in their own habitat after some months of acclimatization.

Diversions are few, a visit to Ollagüe being by long odds the most welcome. At 'Quilcha football is played halfheartedly—think of it when you are climbing Mt. Blanc, *only* 15,800 feet!—but the real games are held at Ollagüe. The chief solace seems to be coca, brought in from the Bolivian lowlands. The dried leaves are chewed with bits of a "biscuit" made from alkaline wood ashes. The efficiency of the extraction of cocaine from this alkaline mixture must be rather high and the use of as much as a pound of dried leaves a day—which is not uncommon—represents a very considerable amount of the alkaloid. The habitués (and abstainers are rare) chew these leaves during most of the day and ascribe to them their ability to withstand not only altitude but cold, hunger and fatigue as well. We regretted that we had no place in our program for a study of this interesting habit, which is common to much of the Central Andes.

Through the great generosity of Señores Don Juan and Don Hipolito Carrasco we were provided with not only transportation service between Ollagüe and the mine camp but also the use of most of the administration building at 'Quilcha.[12]

At first only a small group from the expedition with a limited amount of apparatus moved up to 'Quilcha, blood samples, etc., being sent down to Ollagüe. We found, however, that laboratory work could be done efficiently at 17,500 feet, and eventually the entire expedition, experimental animals and all, was settled at 'Quilcha.

Our activities frequently amused the miners, but they were very friendly and cooperative. We always had plenty of volunteer subjects from which to take arterial blood and samples of the air in the bottom of the lungs (alveolar air). When we told them we were going to establish a camp at the top of the mountain, above 20,000 feet, they said with conviction that neither we nor any one else could sleep there, let alone live there for a week, but they cheerfully shouldered packs and followed us up to help make our camp.

As eventually established, the route to the top was both easy and safe, the gradient averaging about 35 per cent. and nowhere exceeding 55 per cent. The climb up was a long hard pull, but blood and gas samples could be sent down to 'Quilcha in only an hour or so. The camp consisted of two glacier tents and a snow cavern about 7 feet in diameter and 5 feet deep, roofed with tent poles covered with blankets topped by snow. The snow cavern was the principal living quarters and, with its twisted tunnel entrance, effectually shut out the wind which occasionally threatened to destroy the tents. This camp was occupied by successive pairs of men for periods of a week, two days, two days, and a day and a night. From all these men samples of arterial blood and alveolar air were obtained and satisfactorily analyzed.

It must be remembered that, on the whole, our party was very well acclimatized and that for the top camp we selected those who seemed best adjusted. Even so, we were surprised that life at over 20,000 feet can be maintained so long with so little serious difficulty. One member became gravely ill with "soroche" after a day at the top (he recovered quickly when brought down to 12,000 feet), but otherwise it was by no means a case of existing by sheer effort of will in a state of physical and mental torpor.

Reports of mountaineers who were unable to eat or sleep at this altitude had not led us to expect the good appetites and restful sleep we experienced. However, the total food intake was definitely subnormal, as was the time spent in actual sleep. Because of the cold much time was spent in our sleeping bags, but the long waking hours passed restfully.

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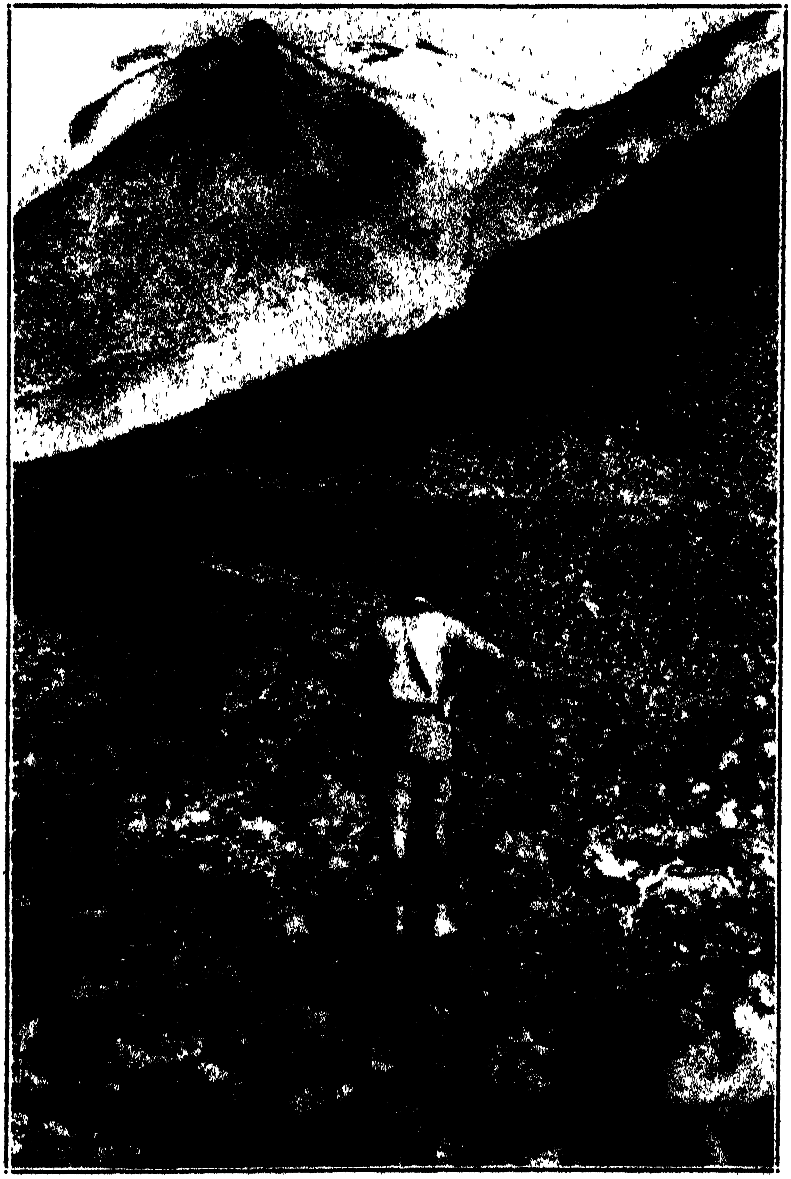
[12] We have not forgotten the hospitality of Mrs. Carrasco at Ollagüe, who kept us from forgetting the amenities of civilization.



CHOOSING THE WAY UP.

THE PEAK IN THE TOP CENTER IS A SHOULDER OF THE HIGHEST SUMMIT OF AUCANQUILCHA.

Smoking was impossible when doing any physical labor, but otherwise was as enjoyable as at ordinary altitudes and our tobacco consumption did not decrease.

The continuous cold was trying and the occasional high winds intensified this discomfort. Preparing food consumed much time and energy—thawing tinned foods in water boiling at 175° Fahrenheit is slow. Cold hands and feet persisted except when walking or after some time in bed. The body, and especially the extremities, is more sensitive to cold at high altitude, and at our high camp (in

CENTRAL SUMMIT RIDGE OF AUCANQUILCHA

AS SEEN FROM THE SOUTHEAST PEAK (NEAREST OLLAGÜE, SEE PHOTOGRAPH ON PAGE 290). THE ROUNDED SUMMIT AT THE EXTREME RIGHT IS THE HIGHEST POINT ON THE MOUNTAIN (20,280 FEET). THE HIGHEST CAMP (PUNTA DE CERRO) IS ON THE SNOW FIELD JUST BELOW THIS SUMMIT BUT IS NOT VISIBLE AT THIS DISTANCE. BETWEEN THE PHOTOGRAPHER AND THE CENTRAL SUMMIT RIDGE THERE IS A SNOW-CLAD VALLEY 3,000 FEET DEEP.

the South American winter) we experienced true arctic cold. Daily maximum temperatures were quite constant, averaging 10° F. Minimum temperatures were more variable, ranging to as high as $-7°$ F. and averaging about $-20°$ F. The lowest temperature during our stay at the top was $-45°$ F.

All members of the expedition lost weight during the stay above Chuquicamata in spite of abundant, varied and generally not badly cooked food. The average weight loss was close to 15 pounds per man, and one member lost 26 pounds. A part of this, however, was merely dehydration, and most of the lost weight was regained in a few weeks at more moderate altitudes. Really fat people are rare at high altitude, though the "chunky" type is common.

On going down to sea level there is little or no feeling of exhilaration, only a sense of well-being, enormous appetite and readiness to sleep twelve hours on end. There is no feeling of "treading on air" or of limitless power. The idea that the person recently from high altitude is a much better man at sea level than the sea-level stay-at-home is probably entirely erroneous. It must be remembered that the adjustment to high altitude involves much more than mere increased efficiency in breathing and in transporting oxygen. For example, the respiratory centers in the brain which control the rate of breathing may have altered in sensitivity and the new sensitivity, nicely adjusted for the high altitude condition, may be ill-suited for sea level. Again, we found that the carbon-dioxide capacity of the blood is greatly diminished in the acclimatized person at high altitude. This is an admirable arrangement at high altitude where carbon dioxide elimination tends to outrun the ability of the body to take up oxygen, but it would be rather a hindrance at sea level.

The detailed results of the expedition are being published in the technical journals by the various members of the expedition. It is not intended to attempt a résumé here; as a matter of fact, at the time of writing not all the data have been analyzed fully and it will be some time before the last of the papers resulting from the expedition are published. However, a few high lights may be given in addition to the points already noted.

As a preliminary, it is necessary to review some of the known facts about respiration at ordinary altitudes. When air is drawn into the lungs it comes into close contact with the blood. The oxygen pressure in the air is considerably more than in the venous blood and the blood tends to take up oxygen from it. The arterial blood leaving the lungs has an oxygen pressure in it not much less than the oxygen pressure in the air in the bottom of the lungs (alveolar air). Only a part of the oxygen in the lungs is absorbed, however, and the amount of oxygen taken up by the blood is dependent upon the oxygen pressure and the amount of hemoglobin in the blood. This hemoglobin, the colored matter of the red cells, unites with oxygen and so enables normal blood to carry about 50 times as much oxygen as ordinary salt solution. But at sea-level air pressure the hemoglobin becomes "saturated" and will take up no more oxygen. Accordingly, at or near sea level, normal arterial blood from the lungs is always nearly (95 to 96 per cent.) "saturated" with oxygen and carries its full quota to the tissues of the body. At low air (and oxygen) pressure, however, the hemoglobin will be only partly saturated and the blood will be deficient in oxygen.

The late Professor J. S. Haldane had suggested that at high altitude the cells of the lungs somehow "learn" to secrete oxygen into the blood. According to this theory, the pressure of oxygen in the arterial blood of an acclimatized man at high altitude should be higher than the pressure of oxygen in the air at the bottom of the lungs This theory had been denied by many, notably Professor August Krogh in Denmark and Professor Sir Joseph Barcroft in England, but the Oxford school could always retort that the subjects were either not acclimatized or that the experiments were at too low an altitude.

We made very careful measurements of the oxygen pressure at the same time in the arterial blood and in the lungs, both in ourselves and in the residents at all altitudes. In no case did we find any support for Haldane's theory; the same process of simple diffusion in the lungs as at sea level could account for all our results.[13]

The acidity of the blood does not affect its total oxygen capacity, that is to say, the total amount of oxygen taken up by the blood is not affected by the acidity so long as the oxygen pressure is high enough, as it always is at sea level. However, when the oxygen pressure is low, the blood is more nearly saturated if the blood is relatively alkaline.[14] Sir Joseph Barcroft pointed out that at high altitude the blood should be more alkaline than at sea level and so should be less unsaturated than would be predicted otherwise. The argument for this change in alkalinity is, in brief: The acidity of the blood is controlled chiefly by the

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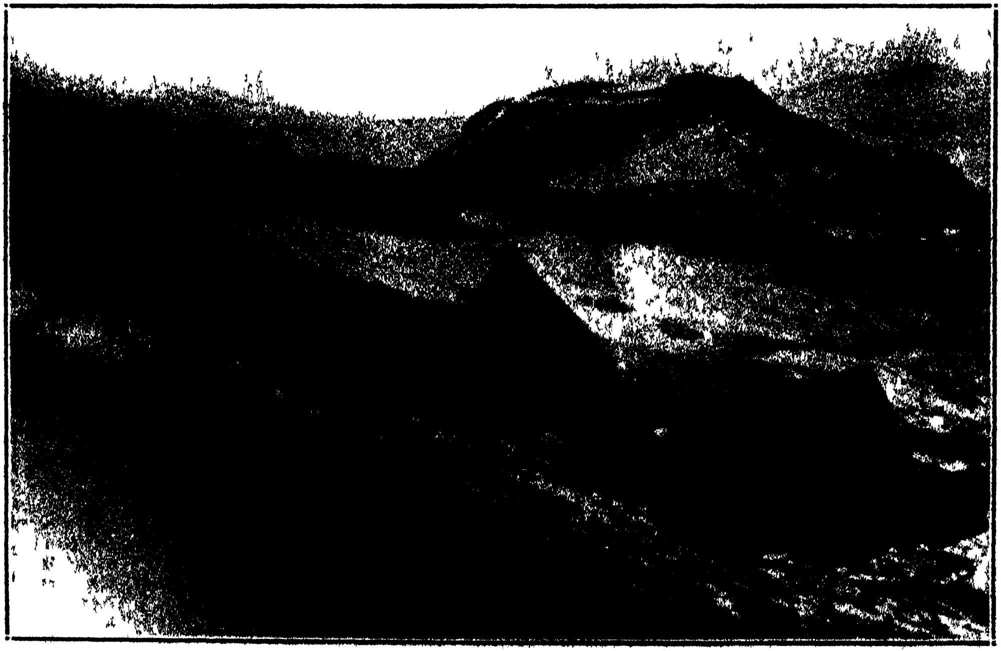
[13] These results were published in the *American Journal of Physiology* by Drs. D. B. Dill, E. H. Christensen and H. T. Edwards.

[14] Eating or drinking alkaline "tonics" or so-called "alkalizing" foods will give little effect and less benefit in this respect.

PREPARING THE HIGHEST CAMP.

MATTHEWS RESTS A BIT



THE HIGHEST CAMP COMPLETED.

THE ENTRANCE TO THE SNOW CAVERN AT THE LEFT OF THE TENTS IS MARKED BY THE ICE AXE. SOUTHEAST PEAK IN THE BACKGROUND.

amount of carbonic acid (or carbon dioxide) in the blood. This carbonic acid is being produced all the time by the body cells and is being removed in the lungs where a part of the carbon dioxide diffuses into the air. When breathing is increased, more air circulates in the lungs, a larger fraction of the carbon dioxide is removed and the blood becomes less acid (or more alkaline). Now at high altitude, the breathing is much increased, and since the production of carbon dioxide is the same as at sea level (*i.e.*, the metabolism is not changed), the carbon dioxide ought to be removed more completely in the lungs and the blood should be more alkaline.

We found that, to some extent, this is true. Our own blood became increasingly alkaline up to 12,000 feet, but above that level there was either no further change or a return to more normal acidity.[15] However, none of the changes in acidity were large except in several men who acclimatized badly. In the miners the blood acidity was the same as at sea level The reason is not that the basis of Barcroft's argument is wrong, but that, at high altitude, the blood changes in other ways so that only a small amount of carbon dioxide is enough to make the blood relatively acid. This is another example of the efficiency of the body in tending to keep the acidity of the blood constant under all conditions.

DR. TALBOTT TAKES A SAMPLE OF ARTERIAL BLOOD FROM THE WRITER AT 20,140 FEET

Barcroft had further proposed that the fundamental affinity (at constant acidity) of hemoglobin for oxygen is increased in the acclimatized man. In other words, though the total amount of oxygen which hemoglobin can hold at *high* pressure is always the same, Barcroft suggested that the hemoglobin from the mountain dweller may unite with oxygen more readily than sea-level hemoglobin.

We measured this fundamental affinity

[15] The studies on blood acidity are being published by Dr. W. H. Forbes, the writer and Dr. F. G. Hall.

THE HIGH CA

of hemoglobin for oxygen in all our bloods at sea level and at every station, including the top camp at 20,000 feet. In addition, we made similar measurements with the blood of three residents at Ollagüe and of eight of the miners at 'Quilcha. All these results disagreed with Barcroft's theory. At the lower stations, Chuquicamata and Ollagüe, there was no change in the basic affinity of our hemoglobin for oxygen and the affinity was apparently normal in the miners At the higher stations there was a slight *decrease* in the basic affinity of our hemoglobin for oxygen. This was partly offset by the slight alkalinity of our blood, so that the net result was to make our blood have about the same amount of oxygen as would be predicted for blood brought directly from sea level.[16]

The consideration which impelled both Haldane and Barcroft to advance their theories was the realization that otherwise it would be necessary to admit that at high altitude the arterial blood, even of acclimatized men, must be greatly unsaturated with oxygen. And hospital experience had shown that when the arterial blood is greatly unsaturated the patient is very sick indeed. However, we found that both our arterial blood and that of the miners *was* greatly unsaturated and to about the same extent in both groups at 'Quilcha. At the highest camp our arterial blood averaged only 66 per cent. in arterial saturation, yet as already recorded, we felt well, able to do moderately hard work and even, or so we believed, able to think straight.

Many mountain-climbing parties previously had found that the concentration of red cells in the blood is increased at high altitude and that the increase is roughly proportional to the altitude. This thickening of the blood was very evident in our party, and we found, in addition, that the oxygen capacity (the total amount of oxygen held by the blood when fully saturated) increases in precisely the same proportion as the number of red cells.[17] The oxygen capacity of the miners' bloods at 'Quilcha was more than 50 per cent. above the average for sea level. Our own bloods increased on the average 25 per cent. These high oxygen capacities would be enough to overcome the handicap of our low arterial saturations if all the oxygen could be given up to the tissues. However, the venous blood always carries some oxygen back to the lungs and the tissues ordinarily suffer if they have to use oxygen at very low pressure. It may be that much of the acclimatization to high altitude consists in the habituation of the tissues to live, not on less oxygen, but on oxygen at a lower pressure.

In any case, the oxygen delivered to the tissues depends on the rate at which the blood is pumped around the body as well as on the amount of oxygen in the blood at any one time. The attempt of the body to make some adjustment along these lines accounts for the fact that when a sudden ascent is made the heart rate is increased even in resting people. In the acclimatized person, however, the simple expedient of pumping faster is not resorted to except in response to work. Our own pulse rates in rest did not increase except in those suffering from mountain sickness, and in several of those best acclimatized the pulse rate was actually slower than at sea level. The miners at 'Quilcha had considerably slower pulses than comparable men at sea level. This is fortunate, since at high altitude the heart is already under some strain from the job of pumping unusually thick and viscous blood. However, at high altitude, relatively mild exercise brings about an increase in pulse rate like heavy work at sea level, and most of the long-time residents at 'Quilcha show some degree of heart dilatation similar to that seen in athletes.[18]

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[16] *Cf.* Keys, Hall and Barron, in the *American Journal of Physiology*, 115: 292–307.

[17] The studies on blood morphology are being published by Dr. J. H. Talbott.

The appetite is apt to be capricious at high altitude, but sweet foods, chocolate and jams are often relished. The blood sugar sometimes may be a little high and dextrose seems to be rapidly absorbed; this is in agreement with the subjective observations of mountaineers and gives point to the decision of the present Everest Expedition to take along a supply of dextrose.[19]

The study of the high altitude animals was of much interest, though we could only scratch the surface of this fascinating field.[20] These animals, llama, vicuña, etc., did not have a very great amount of hemoglobin in their bloods, but we found that there is an unusually great affinity of their hemoglobins for oxygen, and the oxygen saturation of their arterial bloods generally surpassed our own. On the other hand, we were generally superior to lowland animals like the sheep and rabbit. Barcroft's theory works when comparing different types of animals if not for explaining acclimatization in man.

One may ask what are the limits to life at high altitude. The highest peak yet climbed is Kamet (in India, 25,400 feet), but at least six men have surpassed 28,000 feet on Everest. Apart from the sheer climbing difficulties, it is probable that Everest could be climbed without extra oxygen, but that altitude (29,140 feet) must be close to the absolute limit. Birds have been seen in the Himalayas as high as 26,000 feet but, in general, animals do not go above the level where food may be found except when they are pursued. The highest cultivated land seems to be 15,200 feet at Korzok in Little Tibet, but sparse grazing may extend up another thousand feet. Lichens are found higher than any other types of plants and we found many small patches at 20,000 feet.

The limits for semi-permanent human populations may be gauged from the 'Quilcha camp. At 'Quilcha the attempt was made to put the camp closer to the mine. For more than six months a camp was maintained at 18,500 feet, but even these highly selected people were beaten down. They had suffered from increasingly persistent headache and sleeplessness, and now they make the exhausting climb to the mine daily with no thought of moving their camp higher.

It must be clear that there is still much to be done on the problems of life at high altitude. Many false trails have been eliminated and much positive knowledge has been gained, but such questions as the rôle of the body tissues and the activity of the respiratory centers in the brain are almost entirely unanswered. Again, we know next to nothing about the distribution and rate of flow of the blood in various parts of the body. We can say that generally the man best fitted to go to high altitude is strong, active and young, with a large lung capacity and a rather slow resting pulse rate at sea level. But we can not say precisely what determines that one man will be mountain-sick, while his fellow literally feels "on top of the world." Many of us will not rest content until we can return better answers to these questions.

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[18] The heart studies are being published by Mr. Bryan H. C. Matthews.

[19] The studies on sugar metabolism are being published by Dr. W. H. Forbes.

[20] These results are being published by Dr. F. G. Hall and Dr. D. B. Dill.

IN QUEST OF GORILLAS

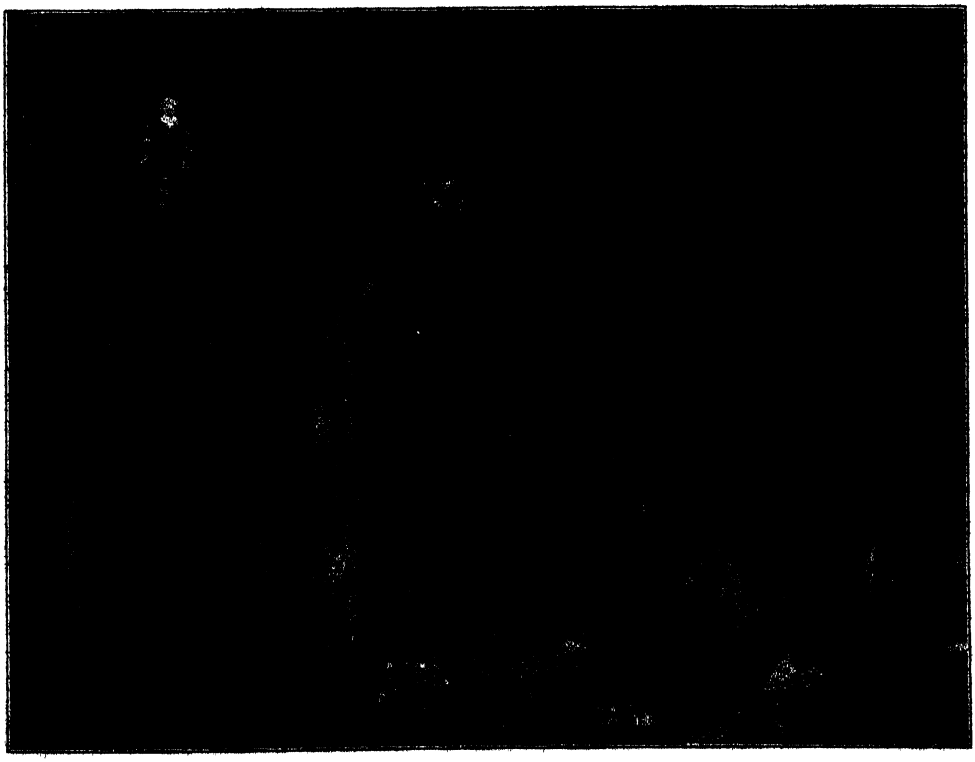
By Dr. WILLIAM KING GREGORY
CURATOR OF COMPARATIVE ANATOMY AND OF ICHTHYOLOGY, AMERICAN MUSEUM OF NATURAL HISTORY, PROFESSOR OF PALEONTOLOGY, COLUMBIA UNIVERSITY

XII. HUNTING GORILLAS IN WEST AFRICA[1]

By H. C. RAVEN
ASSOCIATE CURATOR IN THE AMERICAN MUSEUM OF NATURAL HISTORY; LECTURER, COLUMBIA UNIVERSITY

FROM the village of Ozoum we looked over to the northwest at some rather steep hills, the upper slope of which seemed to be covered with heavy forests, while on the lower slopes there were alternate patches of second growth and native gardens.

Probably no people are more expert in sending and receiving messages by drum than are these West Africans, and drums are to be heard at almost any time of the day or night. After considerable discussion with the head-man of Ozoum, Martin Atangana, it was decided that he should send out word to all the neighboring hamlets, of which there were a number generally distributed on the lower



SOLID COMFORT—FOR AFRICANS.

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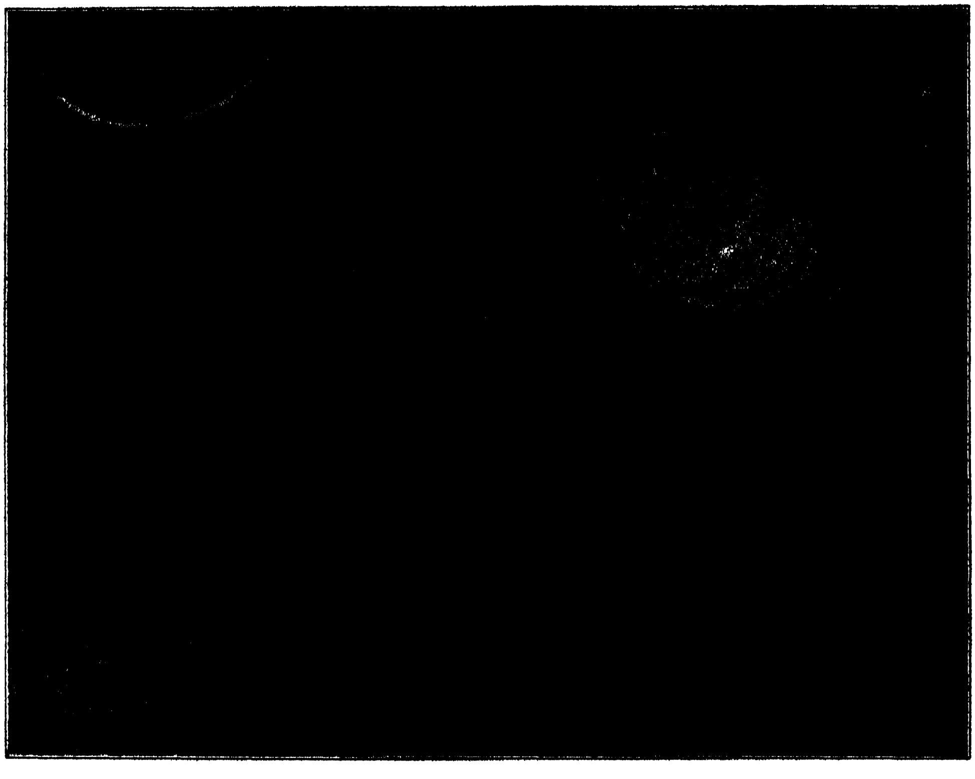
[1] In the previous section I mentioned Raven's indefatigable hunt for gorillas in the forests near Ozoum in the Yaoundé region and later at Vimeli and other localities, all in the French Cameroons. Raven's own story of his adventures, based upon his very full diary and subsequently dictated records, will now be given. —W. K GREGORY.

slopes of the range of hills to the north and northeast of his village. He was to send word that should gorillas be heard or seen he was to be notified immediately, because in his village was a white man who wished to shoot them and who would come to hunt them as soon as they were reported.

On the morning of November 16, 1929, by which time I had already begun to feel impatient, a drum reported the presence of gorillas at a place called Ongke, several miles away. With Martin and a few carriers I left Ozoum at 10 A. M. When we reached Ongke I was told that the gorillas were right over among the plantains. I stepped over the bamboo fence and walked down the slippery incline, for the ground was red clay and it had been raining. I followed the path down toward a brook. On my left there was a dense second growth, while on the right there was high grass and plantains. I had with me one man.

As we walked quietly along the path for 50 yards we could hear not a sound, but suddenly there was the distinct and characteristic noise made by a gorilla when breaking down a plantain or banana plant, a sound very much like that which might be made by tearing to pieces a head of cabbage. We then went on very quietly and could hear the same sort of noise in the second growth on the left and among the plantains and grass on the right, while in the mud of the path we clearly saw the knuckle-marks made by gorillas.



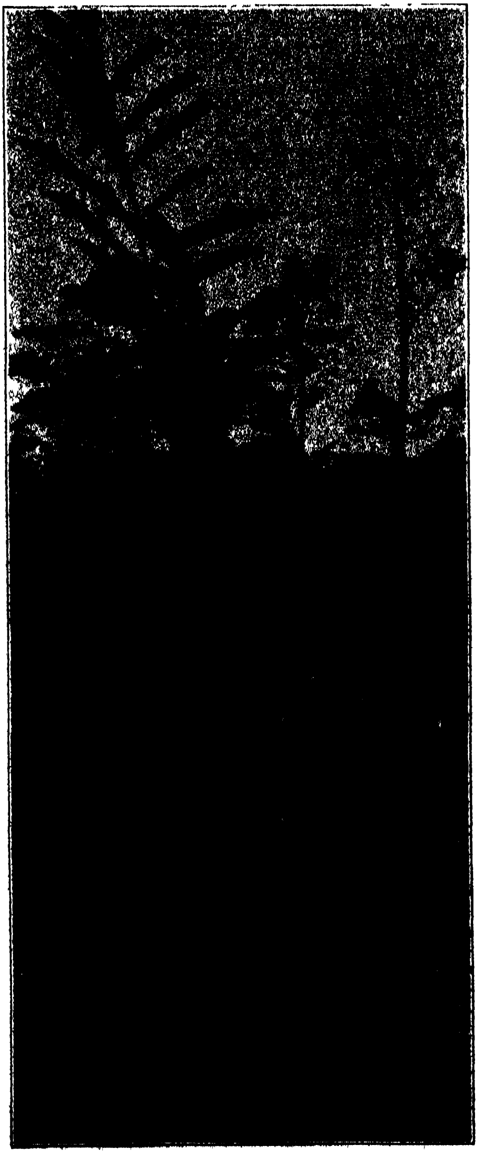
A SUNDAY DISH—DRIED BEETLE LARVAE.

We waited a few minutes, hoping that the animals might cross the path one way or the other; though when they did not we started after them and found

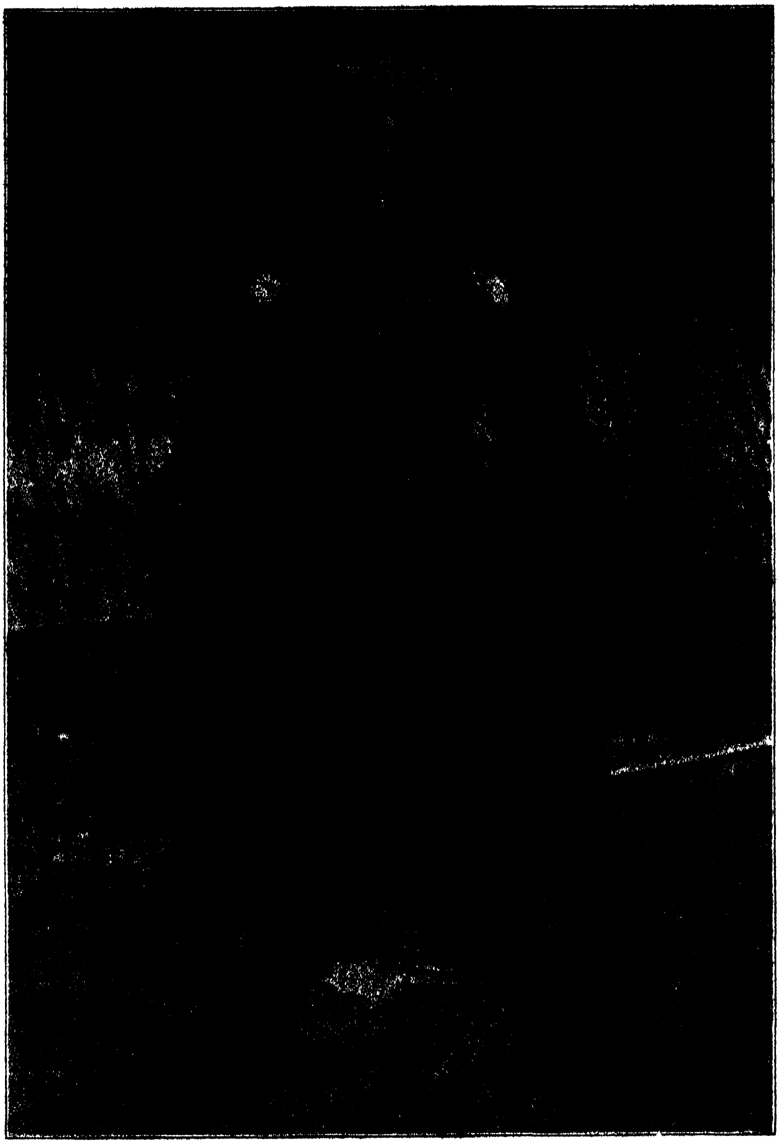
GORILLA DOGS.

that they were moving away. I then thought it would be easier and less likely to scare them away if we walked in the brook. However we had gone only a few yards when we came to a place where gorillas had crossed the brook. We thought they could not be far because there had been no signs of alarm, such as slapping the hands or beating the breast or both.

We found a little trail on the far side of the brook, leading up hill. Most of the gorillas seemed to have gone to the left of this path, but we could hear one ahead and to the right. We got quite close to him because the vegetation was very wet and we were able to go quietly. However, he discovered our presence and we knew that we were discovered, for he remained absolutely still for several minutes. Then when we tried to advance he screamed and rushed at us, though we could not seem him. He



AFRAMOMUM PLANT.



YOUNG GORILLA THAT HAD BEEN CAUGHT IN A SNARE.

stopped perhaps fifteen yards from us and then went quietly away.

We followed as quietly as we could. Twice more he stamped and came forward, then continued for more than a mile, while we followed. One time I caught a glimpse of him in the gloom under the enormous lianas near the trunks of big trees.

Perhaps I should have fired, but I waited, hoping to get a better shot. But we saw no more of him. He went away more quickly than we could follow, and we lost the trail when he reached a rocky place at the headwaters of a tiny brook. He had led us right over into primeval forest and then had eluded us, which he could not have done in the grass and second growth of the type near the clea ings.

We waded around all the rest of th day, trying to catch up again with thi or another group of gorillas but withou success I returned to the clearing an learned that some of that same group o gorillas had been eating sugar-cane whil we were following the single one. I ha a look at the cane, and were it not fo the great strength exhibited in breakin the canes and the fact that the canes ha been torn open by strong teeth where a man would have used a knife, one might have thought that it had been eaten by humans, for the fibrous inner parts had been chewed to extract the juice and the pressed parts had then dropped on the ground. Some of the strong-jawed blacks perhaps could have torn open sugar-cane with their teeth, but when the gorillas do it the marks of the big canine teeth are distinctive.

ON THE WAY TO DJAPOSTEN.

Having failed to get the gorilla, decided to sleep at Ongke, so sent a bo back to Ozoum to get my bed-roll. A he had not returned when I was read to go to bed, I lay down to sleep in little hut, the head-man Martin on on side of the fire and I on the other. W slept on beds consisting of a series o poles like a corrugated iron roof, mad of the stems of palm leaves, hard an smooth and round. These beds hav raised cross-pieces at the head and foot He slept with apparent comfort, but I was not accustomed to that kind of head-rest or foot-rest. The smoke was not so bad when one was lying down, but it was dense, for the door was closed and there was no chimney. It had to seep out through the palm mats, which had been blackened by it until they were like lacquer.

The following day we took a half-dozen natives and went over a considerable area but found no fresh traces of gorilla. That night we ended up at a little village between Ongke and Ozoum. Here the head-man's name was Benedict, which, according to the custom, was also the name of the village. As I had not expected to be away from Ozoum over night, I had brought no food, but it was only about an hour's walk to Ozoum and I sent a boy to bring food from there. The food did not come, the natives had already had their vesper service in the little chapel and it was dark. One of the women of Benedict's household brought food for Chief Martin and me. There were boiled yams about the size of a very large potato, a pure white starchy food, good tasting and of firm texture. Then there was a dish entirely new to me that was called *ngwan* and which I liked very much. It consisted of the kernels of squash seeds dried, peeled and ground on stone, then wrapped in leaves and boiled. I was told that there was meat inside the mixture. It had been seasoned with very hot peppers, which was very much to my liking. We were sitting and eating in the dark, but I found a piece of dried meat about as big around as my finger and a couple of inches long in the *ngwan* and asked Martin: "What kind meat live[2] for inside?" He replied: "Dem good chop; white man he chop 'em." After eating two or three more pieces I examined one carefully by the fire and discovered that they were enormous beetle larvae which had been so thoroughly dried as to be almost tasteless except for a kind of smoky flavor. On another night I was delighted to find

TYPICAL CAMEROON ROAD.

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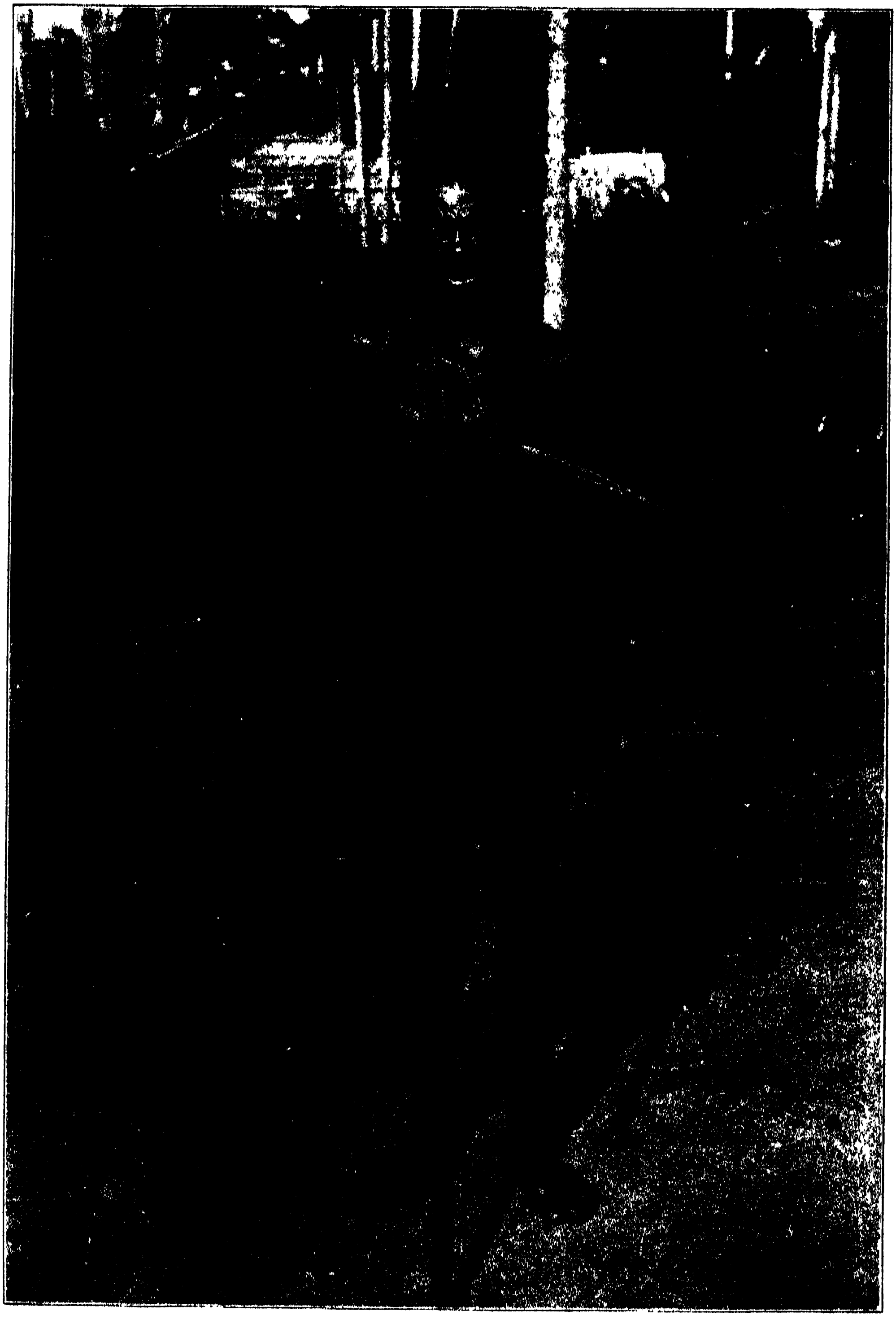
[2] In "Pidgin" the verb "live" does duty for the verb "to be."

PLANTAIN EATER.

a AND *b* GABOON VIPER.



AN ANCIENT WEAPON, THE CROSSBOW.

small prawns cooked in the *ngwan*. They were delicious, and many times later I especially asked the natives to prepare squash seeds with prawns.

I returned to Ozoum on the morning of November 19, having spent two days and nights at Benedict hunting with the head-man. I waited again at Ozoum until the morning of the 21st, and having received no reports of gorillas we started out along a different trail toward the north, parallel with the range of hills. Part of the time it was raining. We passed through several little villages.

At one of these we waited while a man supposed to be a very good hunter was sent for. Martin told me that this man had dogs and had hunted gorillas. However, when he finally came in he proved to be an old grizzled Negro with loose skin about his knees and a pair of typical yellow dogs with up-standing ears. To the neck of one was attached a large wooden bell. These dogs, like all true native dogs, never bark while they are hunting, consequently these wooden bells are used to indicate their whereabouts. One of the dogs had his tail cut off, like a fox terrier. I was told that this was to prevent the gorilla from grabbing him by the tail.

Later on the same morning we stopped at Englebird's village, a picturesque place which sloped toward a stream on the west, from which rose steep hills. The rain made each separate hill and ravine stand out in relief most beautifully.

It was late in the afternoon when we arrived high up in these hills in the midst of a forest in which there was a hut in a small clearing. The owner of the hut pointed out to me a place only a few yards away from the hut, where gorillas had come a few days before. At dusk we heard chimpanzees calling in two or three directions, as the mist settled down over the hills. I passed a cold and smoky night in the hut, the natives sleeping on the other side of a partition.

At dawn a couple of natives were sent out in different directions but returned after about two hours saying that they had seen no traces of gorillas. However, a woman who had come in on a trail in another direction, said that gorillas were further down on the western slope of the hills and we started off in that direction.

At nine o'clock we reached a little village called Tjambolo. We stayed here from the 22nd until the morning of the 26th. The day of our arrival we saw many places where gorillas had been feeding, where they had slept and other signs of their presence. On one or two occasions I could even smell them. Here for the first time I heard mention of gorillas talking at night. One morning natives that lived at the base of the hills told us that gorillas had slept very close to their huts, for they heard them talking in the night, and that the gorillas were probably still there or feeding close by. I went down into the swamp, a place where it was very difficult to hunt because the sun in the middle of the day reached through to the vegetation and small sticks cracked when one stepped on them. However, we got very close to the gorillas and could hear them right in among the plantains and bananas. We could hear their stomachs rumble and see the vegetation move on several occasions. I was once or twice within fifteen or twenty yards of gorillas and caught a glimpse of part of an arm and once a perfect view of a whole gorilla but not for long enough to be able to shoot.

After being close to them for perhaps an hour, we maneuvered around across the small stream in the direction in which they appeared to be moving. There two natives were detailed to go back and follow in their tracks very slowly. It was these natives that the gorillas saw, and they bolted across the stream and away into the forest, splitting up into at least three groups. I had glimpses of several gorillas and a perfect view of one on the bare stream bank, as they were about to cross the stream, but there was no opportunity to fire a decisive shot. We spent the rest of the day trailing them, finally stopping high on the side of the hill where there was a granite ledge that the natives thought the gorillas would surely pass; but as usual, they apparently chose another route. While we were hiding by this ledge a beautiful dark brown *Herpestes*, a large variety of mongoose, came running along within a few feet of me. I went back to the village, shortly before sunset.

During several days at Tjambolo we followed gorillas after finding where they had slept, came close enough to hear them feeding but caught no more than glimpses of them, more often only the waving of grass and vines above. Here they were eating the fruit of the *Aframomum*, elephant-grass, bananas, plantains and some small yellow fruit. In some of the deserted clearings we came upon beautiful orange trees laden with ripe fruit and much fallen fruit on the ground. When we found such a tree we always stopped for a feast on the fruit, but gorillas seemed never to have eaten any of it, although they passed near by. In many cases we saw where they had eaten sugar-cane. *Aframomum* plants were generally distributed in the district, but I seldom saw much fruit in any one spot. In this neighborhood the gorilla feces always contained the black seeds of the *Aframomum*.

Later we followed a forest trail which finally led us to Ongke, and then we went on to Benedict. This completed our circuit of the hills in the vicinity of Ozoum. During this time we saw a place where gorillas had been feeding the day before. They had pushed over banana plants and torn them apart in order to get at the center of the plant. Another time I saw the broken stem of a *Musanga* tree, three inches in diameter, broken off short by a large gorilla apparently in play. This broken tree gave an indication of the gorilla's prodigious strength.

In one place we saw leopard tracks and bits of hair and blood of a small animal which the leopard had overtaken.

On another occasion I saw a native "call" an antelope. He held his nose with his fingers and called "Ngwa-ngwa-nngw-a-a-a," each time louder than before. In a few minutes out bounded a tiny antelope, which I shot. It was about as high as a fox terrier, one of the smallest of living hoofed animals.

While we were on the way back toward Benedict we heard a drum beating. In a minute or so the regular boom-boom-boom-boom signified the end of the message. There was a little pause, and the whole thing was repeated. Martin turned to me and said, "Gorilla live for Benedict," so we hurried on. We left the stream and went up a long incline. As I walked there were more drum messages and Martin said, "They are saying to come quick because the gorillas are there. One gorilla is in Benedict; he is dead. Other gorillas are angry and are staying near by."

We walked as quickly as we could, and when we reached Benedict we found that the place of the gorillas was about three quarters of a mile away. When I arrived at this locality there were a dozen or more natives armed with spears and knives. They said, "The gorillas are right here." They showed me where there was a great deal of elephant grass where one of the natives had had a snare set for wild pigs. His hut was less than 100 yards away. He had just come out of his hut at dawn and was talking with Benedict when they heard a young gorilla scream. The man immediately realized that the young gorilla was in the direction of the pig-snare and perhaps was caught in it. They ran in that direction. There was the little gorilla with the snare drawn tight around his wrist, of course crying, and a big male gorilla trying to bite through the snare. There were other gorillas near by. As the men drew near and threw a spear, all the gorillas drew away and threatened the natives from the security of the dense underbrush. At first I was told that they had speared a large gorilla, but upon further inquiry I decided that they had thrown spears at him but did not know whether he had been hit. As they approached the little gorilla the natives were very much excited. The gorilla was screaming, and when the man went close it grabbed his spear. He immediately struck it with his machete, cutting off its hand. He said his only thought was to make it keep still so that the others would not come after it. He then struck it on the side of the head and speared it in the chest, killing it instantly. We followed this group of gorillas for some distance and spent until the middle of the afternoon trying to come up with them. However, they were thoroughly alarmed and went a long distance over the hills. Upon returning to Benedict I bought the head of the little gorilla from the natives when they had dismembered it. They ate all parts of the animal, including all the viscera. These people were very keen to get any kind of meat. I believe most of them got a meal of meat no oftener than two or three times a week.

I returned to Ozoum, where I found that Drs. Gregory and McGregor had had an interesting time photographing and making sketches of the natives in and about the village. The head-man Martin wanted us to see a French official in Yaoundé and get him to order a native chief, who he said had many people, to combine and make a drive to hunt the gorillas and drive them up into trees. He said we could easily kill all of them. Of course my object was not mass killing and I would not consent to this. I felt that there must be other districts in the Cameroon where they were more abundant. We therefore decided to return to Yaoundé and go off in some other direction. In Yaoundé one of the French officials told us that he had recently been at Vimeli and that the chef de poste there had a very good *pisteur* and that gorillas were plentiful. We decided to take his advice, hired a camion from an English firm and left for Vimeli with our camp equipment and our three black boys.

The chef de poste, M. Juillot was a very young man who was much interested in animals and had many pets, including dogs, cats, a parrot, a mongoose and best of all a baby gorilla. He very kindly invited us to occupy part of his large house. He called his hunter for me and got me a police boy and three or four porters. His police boy was to supply me with porters in any village I might visit.

We walked a few kilometers back along a motor road toward Yaoundé and for several miles over a trail that went off to the right. We passed some little villages and cocoa plantations as well as native gardens of plantains, bananas, caladium and cassava, corn and peanuts. We then got into country where there was more forest and more rolling ground and where there were a number of little streams and some forested swamps.

On several occasions we heard the swish of branches and hoped that we might come upon gorillas or chimpanzees feeding up in the trees. We would listen and walk quietly, but each time we would either see or hear sounds which we knew were caused by monkeys, not gorillas nor chimpanzees. We saw three or four varieties of monkeys, all of the genus *Lasiopyga* and all of them very beautiful.

In one of the swamps crossed by the

trail we saw fresh footprints and knuckle-marks of the gorillas, which we followed. We followed gorillas by sound for two or three hours and then got into a patch of forest where the ground was drier and harder than in the lowlands and where the trailing was much more difficult. We heard grunts and saw the motion of the vegetation and would go stealthily forward; then over in quite another direction we would hear more sounds.

The hunter that I had with me was a wiry, hard-faced, black Negro, who seemed to take delight in ordering the two other Negroes about, gruffly telling them to scout here or there, right or left. It seemed to annoy these native trackers very much that we could not keep on the trail of the gorilla, but this was very difficult to do in the middle of the day when the ground had got drier and we could not see the footprints and knuckle-marks, but only an occasional broken twig. On several occasions we heard noises in different directions.

After shifting back and forth several times we heard a noise close by and were going stealthily, expecting to meet gorillas at any moment. Suddenly a hunter ahead turned and said, "Schwein!" and asked me if I wished to shoot one. I replied that I did not want to shoot and he then begged to be allowed to do so. This native hunter had an old French rifle. I said, "All right. Go ahead!" and he carefully inspected his rifle. There were several red river hogs (*Potamachoerus*) in the group, beautiful animals with long tesselated ears and quite long tails. Out of curiosity I followed just behind the boy as he went up-wind to shoot. He made use of a fallen tree as cover. There were perhaps a dozen animals, mostly just standing still, switching their tails and flapping their ears. The boy went up until he was within less than fifteen yards of the nearest animal, which was a big one. Then he deliberately put up his rifle as he was kneeling and fired. There was a cloud of smoke and a great booming noise from the gun, such as I had not heard since I used to shoot black powder shotgun shells as a boy. I got a glimpse of a couple of the pigs as they ran away, trotting rapidly for a few steps, then hesitating and then going forward again. When the smoke rose we went to find the animal that had been shot at, but there was no sign of it. I could hardly believe that any one could miss a broadside at fifteen yards. There was not a drop of blood or a sign of a wounded animal. Later I learned that most of the black hunters that I met in the Cameroon were just about as good shots as this boy, notwithstanding that they all had charms which they carried in their belts or pockets to guide them aright.

Most of the forest here was thick. We had been walking from early morning. I was getting rather tired, and the boys had lost much of their enthusiasm for tracking. After our encounter with the swine we had been winding back and forth through the forest; it was cloudy much of the time and I had not kept track of our direction with the compass. It was impossible to tell where we were, and the natives did not seem to know.

It was about three or four o'clock when the natives suddenly stopped and turned partly around. I had heard nothing, but they claimed they had heard a gorilla bark. They said it was some distance away, but that unmistakably it was a gorilla, so we immediately set off in that direction. In perhaps a half hour we came upon very fresh signs of gorilla and a few minutes later I saw the bushes move. Here the forest was heavy, but still there was more underbrush than usual in heavy forests. The gorillas were in a group and quite close to cover. Suddenly a half-grown one walked right out into plain view and then I got a glimpse of a very large one. Just as I raised my gun it stepped behind a tree. I could not see where it came out. Then there was another, apparently a large one, moving just behind some saplings and brush and there were still others. One was huge and once when it looked in my direction for a fraction of a second the coloring of its face and the hair of its head were reminiscent of a gigantic drill.

There were two or three big trees in such a position that the gorillas, the big male and the young one which had passed from my view, could come within a very few feet of me without being seen again, so I was alternately watching straight ahead where the group was and to the right to see when the big fellow would come from behind the tree. I saw one that had been moving a sapling fairly distinctly, but when it moved it was in the shade and hard to see. However I fired with a solid metal-patched bullet. There was an outcry and they all fled, the enormous male bringing up the rear. We quickly went in the direction I had fired, and I expected to see the animal stone dead. Instead there was blood.

We followed the trail of the feces, which are always abundant after any sudden disturbance. It was very exciting as we went along finding here and there a drop of blood and expecting to come upon a fallen gorilla. Sometimes the boys would hand me a leaf with a drop of blood the size of a pinhead and we would know we were on the trail of the wounded animal. Once this animal stopped and wiped the blood off on the leaves, and thereafter for some distance the trail was very difficult to follow. But with myself and the three boys scouting along, sometimes together, sometimes several yards apart, we were able to keep the trail very well, though we went very slowly. At about 5 o'clock in the afternoon we came upon a place where there were about a dozen gorilla beds. The group we were following passed right on over these.

The natives complained that we had better try to find our way out of the forest, as it was beginning to get dark and they did not know in which direction to go to find a trail. However, after passing these gorilla beds we had gone perhaps a half-mile when we came upon a well-defined path. It was impossible to follow the trail of the gorillas further. The natives went up and down the path for a little way and then seemed to agree that we should go to the right to find some village or clearing. I think it was not more than a mile to a village where I found my police boy and porters with my bed-roll.

After spending the night at this village, we started out at daybreak and followed the trail of the same band of gorillas. We came upon the place where they had slept. We could even locate the one that had been shot. My bullet had apparently missed the animal's brain by not more than an inch, for it had passed through the nose, and the gorilla's nose is very short. A mushroom or soft-nosed bullet would doubtless have torn the whole face of the animal and probably killed it, but would also have made it unsuitable for preservation in the way we wished. This day we found no more blood on the trail and the hole drilled by the bullet through the animal's face had apparently done little harm.

We came upon one or two other groups of gorillas, but apparently they had been hunted and were quite shy, so finally on the 10th of December I returned to Vimeli, having been out since the seventh. We returned to Yaoundé on December 14.

When we had first arrived at Yaoundé one of the missionaries told me that at a place far in the interior of the Cameroon, named Djaposten, there were many gorillas, that in one morning's walk of perhaps two hours he had counted more than 100 gorilla beds. However, our stay in the Cameroon was longer than we had anticipated, and it was now time for Drs. Gregory and McGregor to start for home. Shortly after they left Yaoundé for the coast on their way home, I left on December 17 for Djaposten by motor-truck, the distance from Yaoundé to Djaposten being 541 kilometers (338 miles). We stopped that night at a native village called Sanken on the northern border of the great equatorial forest region of West Africa.

The road from Yaoundé runs along this northern border of the forest and has been continued eastward by the French and Belgians until now it joins with the roadways of Uganda and East Africa and forms a great continuous motor highway across the continent. This might lead one to think that there was much traffic over this road, but this is not the case. Several times in going back and forth between Yaoundé and Bertua, which is at kilometer 332 from Yaoundé, where the road turns south again into the forest, we met only two or three motors.

This is a very picturesque country. Even where there was savannah there were often gallery forests in the depressions. There were people scattered through this country, and at Bertua there were real savannah people with a somewhat different culture from those of the forests. They built large round mud-walled houses, with grass thatch. They kept many goats and sheep. The people themselves were darker and appeared to be more brachycephalic than those of the forest. This was especially noticeable when they were grouped together at the market. There were a few cattle here, but I believe they had been brought down from the north.

The country about Bertua and over much of the road between Yaoundé and Bertua seemed very fertile. In most places the soil was red and supported either a luxurious growth of grass and acacias or else rain forest. When it was possible to make a choice, the natives always chose to make their gardens where there had been rain forest, not in the savannah, perhaps because weeds would grow less at first in the forest. Beside the road in many places the natives, by order of the French Government, had planted plantains, bananas, cassava, caladium, sugar-cane, corn, sweet potatoes and other food plants, in order to supply food for people working on the road.

This was a fine road, though in some places the bridges were very poor. They were replacing the wooden bridges by ones of reinforced concrete. I often thought what an enormous amount of labor could be transferred from road-building to the production of food crops if the steam-roller were used to pound the road instead of the natives with wooden blocks; for it requires a great number of natives to carry gravel in loads on their heads and others to pound the surface of the road with wooden mallets, and nearly every foot of the thousands of miles of road in West Africa has been treated in this way.

The second day's journey from Yaoundé brought us well down into the forest. Early in the afternoon of December 18, 1929, we reached Abong Mbang and had just passed beyond the Government Poste when I was told that there was an American doctor, Dr. Lehman, at Abong Mbang. I ordered them to turn around that we might go to see him and then was told that his house was about 6 kilometers from Abong Mbang and that he was not at home but would be back in a month. So we continued on toward Djaposten.

Just at dusk we reached a rather large native village. The chief was a very tall Negro, very quiet, dignified, with very deeply sunken eyes, whose name was Atangana Impene. He was building a large new house, the frame-work of which was already up. There were several rooms and a high-peaked roof and the latticed walls ready to be plastered with mud. This structure looked like an enormous and intricately-made basket, for there were no nails used in its construction. Everything was either crudely dowelled or fastened together with rattans. This chief had shoes and wore clothes like a white man. Later on he put a board floor in this house, the floor being raised up from the ground and a terrace built up around it on all sides. He later said that this was so that you could get that peculiarly pleasing sound that one gets when walking across the bare board floor with heavy shoes on in a white man's house.

At Atangana Impene's village the night was misty and quite cold. I slept in a new house, the mud walls of which were still damp, and there was a tendency for the mud of the floor to stick to everything. As in any typical native house, there were but two tiny windows close under the eaves. Even in the middle of the day one would hardly be able to see without artificial light. He had put this house up especially for European visitors. The rooms on either side had been closed, but the foyer had been occupied by goats and sheep, which made it smell like the rest of the village.

Since leaving Abong Mbang the country had become very hilly, almost mountainous. In most places the road was good, but in some places the steep hills were badly washed. We left Atangana Impene's village about 7 in the morning and reached Djaposten about 8:30. There were no villages between the two places. When the natives of Djaposten heard the sound of the motor truck they came from their houses, which were back a little from the roadway, and congregated along the road. The driver stopped where a group of natives had gathered. I got down from the truck and asked, "This is Djaposten?" A rather short, stocky, flat-nosed Negro with a large black felt hat, white trousers, khaki shirt and no shoes, stepped forward and offered me his hand. "Me be king for dem town." His name was Ngom. I asked him where the mission was, for I had understood that the American Presbyterian Mission formerly had one of its men stationed here. Several of the natives replied in unison, "Mission live for up." Therefore we climbed back on the truck, the chief coming too, and started up to the Mission a kilometer farther on. Most of the group followed along behind or beside the truck.

Here was another small group, one of whom was pointed out to me as the "man for Mission," this one, "black doktor," in other words, one of Dr. Lehman's medical boys, stationed here to dispense certain medicines to the natives. I informed him that I had been at the American Mission in Yaoundé and upon their advice had come to Djaposten to hunt gorillas. I told him I wanted a house. He said "White man's house is right over here." We were able to get the motor truck up to this house, where all my paraphernalia was unloaded. No white man had lived at Djaposten for some time.

At Lomie, thirty-six kilometers further on, there was an outpost of the French Government. I decided to go on immediately, while I had the truck, to Lomie and present my credentials to the French officials there. The chief of Djaposten, Ngom, asked if he could go with me to Lomie and Dr. Lehman's medical boy, Ntje, also wished to go in the truck to bring back a sick woman and child. So I told them to climb on the truck. Parts of the road between Lomie and Djaposten were especially steep and rough. I found the two French officials, M. Geandin, *chef de subdivision,* and M. Vidot, *agent special.* I showed them my credentials and told them that I wanted to hunt gorillas in the neighborhood of Djaposten, that I wished to bring the gorillas out entire and for that would require a number of porters. I requested that the chief be instructed to supply me with twenty or thirty porters should they be required. This was done and I was also told that the government wage rate for porters was 2.25 fr. per day for 25 kilo load. They transcribed some of my papers, especially a letter from the Governor of the Cameroon. We started back to Djaposten early in the afternoon.

The following morning, December 20, with Ngom, one of my boys, Ndongo, and a local native, we hunted for gorillas to the north and east of the road. We started early in the morning and went over much swampy country and second growth. I saw six nests of gorillas, all of which were old, and one or two gorilla tracks that were fresh. We came upon a herd of *Potomochoerus,* and one of them, a large boar, I shot.

On the way back we saw an interesting fish-trap, where a stream was dammed with palm leaves and the fish, in trying to go down-stream, were caught on a lattice of palm petioles. Just before we reached this fish-trap, near the roots of a huge forest tree, there was a large rat that had been caught in a snare set in a hole under the roots. Ngom very deliberately crushed the animal's head with his knife and smiled as he slipped it in a fold of his cloth. I asked him if he had set the trap. He smiled again and said, "Another man made it." It had apparently been set by one of the men who had made the fish-trap. Ngom showed them the rat, and though I did not understand exactly what they said, it was evident that if a man wanted animals from his own traps it was his business to visit them early.

It was late in the afternoon when two natives arrived, carrying the boar on a pole, and everybody else in Djaposten arrived also, to help them take away the meat. I took what I needed for myself and what I thought would be sufficient for the boys, and then gave the rest to Ngom. For the rest of my stay at Djaposten, almost a year, I heard complaints about the careless way in which I had turned over the meat to Ngom, and that this man or woman had not received any. The following day I arranged with Ngom for ten carriers to take my outfit to some place up the Dja, where he claimed gorillas were abundant. About 9:30 a native came in with Ngom and said that gorillas had kept him awake all night at his clearing. We went with him about three miles to his clearing and hunted in the neighborhood for three hours without seeing any mammals. I collected a specimen of caecilian, a wormlike amphibian. As it crawled on the dark, damp leaves of the forest it looked like a giant earthworm, bluish-gray in color, about a foot in length. This is a rare animal in collections and Dr. Noble told me upon my return that this was the first specimen to be collected by a Museum expedition.

Much of the forest through which we hunted was large second growth, where the most abundant tree was the umbrella tree, *Musanga.* This grows to be quite a large light-barked tree with a palmately compound leaf and frequently with roots that branch from the trunk several feet from the ground, and look like braces to support the trunk. In this sort of country there seems to be an abundance of food for chimpanzees and gorillas. They both feed to some extent on the leaves, bark and buds of the *Musanga.*

I had expected to leave Djaposten on the twenty-second of December, but we again had to postpone going inland because a boy ate so much pig that he was very sick, and the others said they were Christians and could not work on Sundays. Finally we left Djaposten on the twenty-third of December and followed a trail north of the Dja toward the east, and spent the night at a place called Malen, which consisted of one filthy hut occupied by two families. Malen was about two hours' walk from Djaposten, and the country was fairly level.

Large plantain-eaters are common in the forests here, called by natives "kunduk." Their calling in numbers is a common sound, especially in the morning and evening. They are beautifully colored birds, blue, green, yellow and black. A smaller variety is much less abundant. One time I shot one of these smaller ones for food. I had been told years ago that the red pigment containing copper in the wing feathers of these birds would soak out in water. I put a few of the feathers in water but after two or three days none of it had soaked out that I could see. The feathers lay around on a little stand that one of the boys had made for my washbasin. Some soapy water came in contact with the feathers, and the red pigment immediately washed out; putting it in soapy water I found that it tinged the water pink and the feathers also changed from red to pink.

We spent one night at Malen and then decided to move farther up to a place in the forest that Ngom called Kinoa-Mpanga. We left Malen early in the morning and traversed rather flat country and four streams. Near the streams were palm swamps. Most of the forest was heavy, perhaps some of it virgin forest. I saw gorilla and chimpanzee tracks in a swamp; in one place there were elephant tracks. Several monkeys were seen, most of them a species of *Lasiopyga* with a red tail and a white moustache, probably *L. cephus.*

Ngom and I led the way in the march to Kinoa-Mpanga. At one place where the forest was fairly thick, Ngom turned to me and said "Antelope," and pointed. I knew from what he said that the animal was quite close. I froze and hesitated for several seconds, trying to see it but I could not until it leaped away, when it was too late to shoot. It was a red forest duiker.

It was just after mid-day when we arrived at Kinoa-Mpanga, a place in large second growth but quite close to original forest. The closest permanent dwelling-place was the hut we had left that morning. At Kinoa-Mpanga were five huts built, about a year before, by Ngom and his people when they had come to hunt and gather rubber. The huts were only a few yards from a stream which is a northern branch of the Dja. That afternoon Ngom and I hunted northwest from camp until dusk. We saw a number of monkeys, squirrels and large horn-bills but no gorillas nor chimpanzees, though we did see some beds.

On Christmas Day I was hunting with a powerfully built young fellow, named Nkoul, and Ngom. About noon we came to a palm swamp. These swamps have a stream meandering through their center, and from the stream to the edges of the swamp there is mud from a few inches to a foot and a half deep. The palms, beautiful and enormous, were raphia palms which do not form trunks. I usually took off my boots and socks when I came to one of these swamps in order to have them dry when I reached the other side. I had just taken them off on this occasion, when a squirrel, saying "ch-ch-ch-ch-ch," ran up on a palm leaf and then jumped to another on a nearby tree, the hairs on its tail all standing erect. I tried to get a shot at this animal with a .22 rifle, and in order to do that I followed it toward the center of the swamp. By the time I had reached the stream the squirrel had disappeared, Ngom was beside me, but Nkoul had disappeared. I inquired where he was and Ngom called. When Nkoul answered, Ngom turned around and said "Small beef," which may mean any sort of small animal from a mosquito to a goat. I said "What small beef?" and he answered "Nyo," which was so much like the Kiswahili word *nyoka* for snake that I recognized it and followed him in the direction of Nkoul's voice. As we approached through the soft mud on which were scattered palm leaves I saw the body of a snake that was about seven inches wide. At the first glance I thought it was a python and said to Ngom, "Where is its head?" Then I recognized by its scales and color that it was a Gaboon viper. Ngom meantime had walked right by the body of the snake within two feet, and in answer to my question pointed straight down, saying "Here is its head." Nkoul had cut a sapling about an inch and a half in diameter and five feet long. Now they split one end of it and sprang it open, then kicked the leaves off the snake in a most careless way so that I warned them, "This snake be very bad," to which Ngom answered, "Ya. Snake he bite, man he die." They then proceeded to place the open split end of the sapling over the snake's neck just behind the head and gave it a sudden sharp thrust down into the mud. With that the snake writhed and opened its mouth, and as they raised it up with its neck wedged in the stick its fangs were erected and it squirted venom several feet.

They told me that this snake was very fine eating, and indeed the flesh was very delicate, tasting more like frogs' legs than anything else. When we reached camp I preserved the skin and head. The animal measured just five feet in length. Its flesh was white and very delicate. For dinner that evening we ate the flesh of the viper and some prawns. Both were very good. The prawns had been caught by some of the women who had followed in the wake of their men folk. The thought of eating a viper seems repulsive to people at home and it would in camp, too, if there was any one about to make fun of it or turn up his nose at it; but when meat is scarce and every one is saying what fine meat it is, then one goes by the taste.

Two days later another squirrel chattered and another viper was discovered after a good deal of search, lying in the leaves not fifteen inches away from the spot where I was standing. This was likewise secured with a split sapling and was duly eaten in its turn. Ngom claimed that in the daytime several men walking Indian file could each step on that snake and the snake would not move, but that at night it was a very different story, because the vipers are very active then. Indeed the natives were so much afraid of the vipers at night that most of them refused to go out with me at night in the forest, as I frequently did whenever gorillas were known to be nearby.

I had taken along many more carriers than were necessary for this camp, for I expected to get a gorilla any day and would require them to carry it to camp and back to Djaposten. However, day after day we hunted without success. There had been a dozen or fifteen men in camp. Ngom had ten or twelve wives, two of which followed along when we left Djaposten to carry his food and belongings. But every day or so one or two more would arrive bringing food, while some that had come out first would disappear. A number of the porters had their wives come out with food, some of the women also bringing children, until our camp numbered about thirty people. It was interesting to see them at close quarters.

I was amused when Ngom and I returned to camp in the afternoon or evening at the casual yet dignified way he would greet any of his wives that had arrived during his absence. They would come up and offer their hands, which he would take with some word of greeting. The women would then turn and walk away. Later on the new arrivals would invariably bring him food that they had prepared. One of them who had come out with us from Djaposten had not gone back but stayed in camp. This one was an older woman. I understood that she was Ngom's oldest wife and she acted as though she were the head of the household. Sometimes when a new wife arrived this woman, who could speak pidgin English, told me that this was another of Ngom's wives.

Frequently the women would catch small fishes and prawns in the stream by selecting a place where there was a bend and the water was shallow and where there was an overhanging bank. Here they would make use of all sorts of debris, sticks, leaves, logs and mud, to build a dyke, thus walling off a little part of the stream. When they had this enclosed they stood in this with their feet wide apart and using a flat basket as a scoop, bailed out the water. Then they wallowed about in the mud to find the many varieties of fishes and prawns. Characins and cat-fish predominated. I made a habit of selecting specimens of the various types they collected, but frequently by the time I reached camp in the evening they would already have smoked the day's catch upon the little woven mat-like structure which they hung over the fire.

On several occasions the men tried their hands at fishing, but they were not satisfied to do it as the women did. The men made basket-like traps which they placed in the stream, usually two or three abreast. The mouth of this basket-like structure headed up stream. Then men stood beside this basket with long knives, while other men were armed with very long saplings, the large end of which had been pounded against rocks until the whole end was mushroomed and brush-like. Starting far above the point where the baskets were placed, the men stabbed at the water with these poles, each thrust causing a loud *"pwok!"*, which must have made a great concussion in the water, for fishes hiding under the bank would dart out and flee downstream away from the disturbance. They would be driven into the traps or often killed by the knives of the natives carrying the traps as they tried to dart by. The commonest fish caught in this manner was a long-snouted characin about a foot in length, which was fairly good eating.

The people at Djaposten were very poor. At the time of my visit they had no means of disposing of anything for money to the traders at Abong Mbang or Lomie. Previously they had been in the habit of gathering wild rubber and wild coffee. I saw a number of wild coffee trees in the forest. But the traders were not accepting either the coffee or the rubber at the time of my visit. Occasionally I could get them to bring a few eggs from Djaposten. However, the commonest food that they would bring out would be large plantains, cassava, caladium and, once or twice, sweet potatoes. Consequently meat was scarce. I always took a 22-caliber rifle as well as a high-powered rifle with me when hunting. Then if there were no gorillas about I would shoot monkeys, which we ate. The flesh of these animals was very good, much better in fact than any of the goat's we had had in East Africa, though the young goats and sheep that I had in the Cameroon were very good.

One or two of the natives hunted with crossbows during the day. Once one killed a monkey, but as a rule they came in empty-handed. I was getting dissatisfied with this locality, and one day Ngom asked permission to go to another place some distance off on the south bank of the Dja. He was gone from dawn to 2:00 P.M. When he returned he had with him two fine monkeys he had killed with his crossbow. He told me that he had seen gorillas and that we could surely find them there.

On December 30 we started soon after daybreak and followed the path south toward Malen for about two miles, then we turned southeast and crossed the Sa and later the Dja. We took embalming fluid and several natives as far as the Dja. Then Ngom and three of his best men went on with me, crossing the Dja on the trunk of a fallen tree. Ngom and one of the others carried their crossbows.

Beyond the Dja was a palm swamp where we saw gorilla tracks. Beyond that we hunted through heavy forest and second growth alternately. At 11 A. M. we came again to the border of a palm swamp, where there were fresh gorilla tracks. There was a chimpanzee nest, that I photographed, in a tree just at the edge of the swamp.

As I was doing this we heard a gorilla in the distance, and a few minutes later started in that direction. Ngom and I went along, leaving the other three behind. It was difficult to follow this gorilla through the heavy forest; for yards at a time we might be led onward only by a faint knuckle mark, a broken twig or a bit of chewed-up *Aframomum* plant. Many times we were quite far from the trail when we heard a branch break or some vocal sound that led us back toward them. They moved about in the forest as quietly as a cat walking across a carpeted floor. Frequently we got close enough to them to see the vegetation moving, sometimes in two or three places at once. Then apparently the group would move off, while one would remain behind. We would think that the whole group was still before us. Then apparently the one behind would go off, without our knowledge, of course, and we might wait for some time believing them close by. Then we would walk very carefully forward, taking advantage of all cover, only to find that they had left perhaps 10 or 15 minutes before. One time we were quite close to one when nearly a hundred yards ahead another had climbed a large tree bearing fruit about the size of a croquet ball. We could hear the swish of the leaves and then the beating of the fruit as it struck the ground like falling apples. However by the time we were able to get close to the tree, they had gone on.

About 2 P. M. we had been close to them for some time. I saw vegetation moving, and at one side there was an open place which I felt sure they would come into. I had my rifle raised, ready to fire, when a large antelope walked out. Apparently it had been hiding there and had been disturbed by the gorillas just beyond. Finally late in the afternoon we succeeded in getting ahead of this group in the direction they were going. Then for no apparent reason they went off at right angles. We followed; we saw their arms move on one or two occasions and I followed, absolutely sure we would get one or two of these gorillas. We had been very close to them for a long time and it seemed impossible that they could avoid coming into view. They seemed to be following down a little depression.

We made a detour, following back trails and were just at the edge of the depression when we heard gorillas in several directions. Suddenly I turned to the right and there I saw facing me a gorilla, standing in the open, but it was not an adult. It was pure black and about the size of an adult chimpanzee. We were face to face. I aimed at its head and then I realized that it was not the gorilla I wanted. It looked at me a moment, then turned and went on down the depression, not going back with the rest of the group. As soon as it was out of sight it made a noise like beating its chest or clapping its hands, and instantly all the others were silent for a minute or more. This was followed by a terrific roar and stamping by a male, and we waited, expecting them to charge. We did not wait long, however, for I knew they might go away and this was what they did. We followed a short distance to find that they had been frightened, as shown by the feces. It was then too late to follow further, for the sun was low. By walking very fast we reached camp just after dark.

On December 31, 1929, I loafed in camp until late in the afternoon. Then I went out to hunt for meat for dinner. I shot a hornbill and a red-tailed monkey, a female with active mammary glands. I asked Ngom who had made these clearings round about our camp years ago, where there is now such large second-growth forest. He told me that during the war the Germans were occupied in fighting and could not control the natives. Consequently many natives had run away and it was some of his own people that had come away off here, far from any village, to establish themselves away from the white man's demand for labor.

One morning the natives asked me if I had heard gorillas talking during the night. I said no, that I had never heard gorillas talking. They said that gorillas had talked at night and that they had heard them. I told them that in the future if they heard gorillas talking they were to wake me, and a night or two later they did so. There was a sound like the twang of the string of a bass viol, very deep and resonant. I presume that this noise was made during exhalation, accompanied by a rapid vibration of the lips. I kept track of how often this sound was made and took a compass bearing on the direction it seemed to come from. The following morning we set out in that direction and eventually found a place where gorillas had slept, but were unable to trail them more than a short distance through the comparatively dry forest where their feet made no impression.

The weather continued clear and dry in the middle of the day, but by midnight it was cold and the forest dripping like rain. This continued until after sunrise. In the heavy forest the leaves of the forest floor do not get crisp before about noon. Mist or low clouds often obscure the sun until 10 or 11 A. M.

While hunting gorillas I took the .22 rifle along and occasionally shot a monkey or a hornbill for food. On two or three occasions I got forest guinea-fowl. Several times we saw tracks of the giant forest hog, *Hylochoerus*, and more often those of the red river hog, *Potamochoerus*.

Nearly every time that I saw elephant tracks I could also see the tracks of pygmies who had been hunting the elephants. Whenever these little people are lucky enough to kill an elephant or wound it severely, they will follow it until it dies, and then call their companions, who come and live where the elephant drops until it is eaten up, as it is easier to move a pygmy village than an elephant. They then carry away the tusks, which they take to the chief of some village and trade for iron and perhaps gun powder or cartridges. The French government allowed certain of the native chiefs to have shotguns. These were not ordinary shotguns but old bolt-action army rifles bored out and made over into twelve-gauge single-shot shotguns. The chiefs in turn sometimes turned over such a gun to a group of pygmies, who were ingenious little hunters. They would procure meat and ivory for their larger Bantu neighbors in exchange for peanuts, maize, bananas, and so forth.

On only one occasion did I see the tracks of buffalo.

Sometimes the natives would get honey from bees' nests within tree trunks. One afternoon I got one young of a large species of owl as it flew from a tree we cut down for the honey it might contain.

It was with difficulty on one or two occasions that I tried to go in the direction of the gorillas at night. The natives disliked walking in the forest at night, and some absolutely refused to do so. I was never successful in getting near the gorillas at night. Either they would stop talking or we would find that they were too far away.

On one occasion I left camp alone very early in the morning, expecting to return within an hour or less, when I came upon fresh gorilla tracks and followed them. Sometimes I could follow their footprints; at other times I heard their voices in the distance, so that I was guided alternately by their voices and footprints At times I was so close that I could hear the vegetation rustle, so I continued on their trail throughout the day. Late in the afternoon they went up a large tree for fruit and only just came down before I got there. This was in the densest sort of jungle; many of the larger trees had been blown down by a storm so that there was just a tangle of fallen trees overgrown by lianas and rattans. It was clear that I could not get back to camp, as beneath the dense canopy of vegetation it was already getting dark. I therefore looked for a place to sleep and found a tree which probably had been struck by lightning and splintered. I could break off bits of the wood and make a fire. I gathered large leaves which I flattened beside the fire and spent the night right there. I thought if I fired a shot there was a bare possibility that the natives in camp might be able to hear it. Fortunately a wood pigeon came nearby and the shot served two purposes. The pigeon, struck with a heavy rifle bullet, was almost blown to bits, but what remained I made a meal of.

I had begun to doze about nine o'clock when I was suddenly aroused by a noise which I recognized as a gorilla talking, but this noise was as loud as the roar of a lion. It seemed to me that these gorillas could not have made their nests more than a hundred yards away from where I lay, so loud was the noise. They may repeat this talk or call or tremendously amplified growl many times. On this occasion of course I felt here was my great chance. If I had had an electric torch or other light I could certainly have found the place where those gorillas were sleeping, but as I was situated I could do nothing. During the night I got so cold that I divided the fire in two and slept between the two fires, as dew continually dropped from the trees above. At dawn I started hunting for the gorillas, hoping to catch up with them before they had gone far. However, in the dense underbrush it was two hours before I located the place where they had slept. I had had only a handful of peanuts and the pigeon to eat, therefore gave up the pursuit of the gorillas and tried to find my way back to camp, where I eventually arrived about noon to discover that most of the natives were out looking for me, but none in the direction from which I came. They claimed they had heard the shot that I fired the evening before, but apparently no two agreed on the direction of the sound.

(The next section entitled "Men, Gorillas and Sleeping Sickness" by H. C. Raven will be printed next month and will conclude the series "In Quest of Gorillas.")

FOSSILS IN PENNSYLVANIA[1]

By Dr. BRADFORD WILLARD

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It has been my experience as a geologist that the average American citizen's knowledge of fossils varies greatly in different parts of the country. Some might attribute this to climate, innate intelligence, ancestry or occupation. I offer no explanation, but merely record my observations drawn from experiences ranging from New England to California that some parts of the population are more conscious of the presence of fossils than others.

Mention fossils to a western rancher, and the chances are that he will produce from somewhere about his shack a few fossil bones or teeth that he has picked up thereabouts. Finding this common bond of interest, he may volunteer to lead you to some neighboring "draw" and point out fragments of an ancient skeleton protruding from the partly eroded bank. Take one of these chaps in the field with you on a fossil hunt, and you may be surprised by his familiarity with details of these long-dead creatures. But mention fossils to an easterner, and observe the mental reaction.

Let us suppose that you have just answered negatively the standard question, "Hey, mister, lookin' for gold?" and told your inquisitor that you are digging fossils. If he still evinces any spark of interest, he may inform you that he has some arrowheads at home or that his cousin found some "mineral rock" in a cave "back in the hills"; or he may even confide in you that he knows somebody who has a collection of old postage stamps! Needless to say, these articles are hardly to be classified as fossils. Not long ago a certain brand of gasoline was advertised by "stickers" depicting dinosaurs. While buying this brand of "gas" at a station in central Pennsylvania, I casually told the attendant that I had found, within a few miles of that very spot, the foot tracks of just such animals as the "stickers" showed, imprinted in stone. Aware that dinosaurs were reputedly large, he allowed that they might have been heavy enough to impress their tracks in the solid rock. Sceptically polite, his feeling of relief when I drove off without becoming violent must have been profound. Nevertheless, be it due to the vicious effect of heredity or not, my small son collected the "stickers" with avidity. Then, while accompanying me on his first visit to the American Museum of Natural History, he astonished to muteness an obligingly attentive guide in the Hall of Reptiles by pointing out with no uncertain gesture and in unsubdued tones such examples as *Triceratops, Stegosaurus* and *Trachodon.* The gasoline "stamps" had done one bit of missionary work.

But, just as all westerners are not necessarily born paleontologists, so all easterners are not indifferent to fossils. Sometimes in the field I have met one "just queer enough" to care about rocks even if they never put a penny in his pocket. More than once it has been my pleasure and good fortune to go a-field with such, and I assure you that the benefit drawn from their enthusiasm over the local geology far eclipsed what little "scientific" return I was able to make. Now and then into my office comes some one wanting to know about the rock full of "petrifications" he has brought to show me. The chances are that my visitor is either a farmer or a Boy or Girl Scout; for, after all, these seem to be almost the only non-scientifically trained people nowadays who have any particular interest in what their eyes show them outside of the cinema houses. And so, I set aside my work and try as best I may to explain that the shells or leaves in the rock are actually the remains of prehistoric animals or plants which once lived in Pennsylvania. And I tell my visitor how these fragmentary remnants entombed in the rock once lived and that then the rock was loose sand or soft mud which later hardened after the dead remains were buried. Call it proselytism if you will, but perhaps there are just enough people interested so that the account which follows may not prove entirely a journey through "the valley of dry bones."

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[1] Published with the permission of the State Geologist of Pennsylvania.

The majority of the rocks of Pennsylvania (unknown to most of us) are probably fossiliferous, that is, they carry enclosed within themselves the remains of strange, long-dead creatures and plants which once constituted the leading citizenry of the Commonwealth. Tell this to most people, and they'll cut you off their calling lists, where only "rational human beings" belong. Yet, wherever one encounters rocks formed in regular layers, even though these layers or beds are tipped and broken, bent and twisted, if they be not too badly damaged, the chances are that you may find fossils in them. At least it is worth while looking over the flat surfaces, and perhaps supplementing this labor by hammering to pieces a bit of the rock. Usually, it will break into layers, and perhaps on some will be found the delicate tracery of a "fern" leaf, the beautifully symmetrical, many-ribbed imprint of a sea-shell or a curious foot track. Our fossils are not confined, you see, to the plants so commonly brought back as "souvenirs" by visitors to the coal fields. On the contrary, these coal plants, interesting as they are, constitute but a small part of the fossils discovered or discoverable in Pennsylvania. The rocks within our borders contain remains of nearly every common kind of marine animal, besides fossils of land-living, air-breathing creatures of many and diverse sorts. Fossils can be found in almost all counties of the state except the southeastern corner. Here the rocks have been so crushed, broken and changed that all semblance of fossils, if any ever were present, is probably destroyed.

How came these fossils to be in the rocks of Pennsylvania? Long, long ago, the geography of what we call the Keystone State was far different from that of the present. You had already guessed this when I told you that our bedded rocks contain fossils of animals which lived in the sea. What was that sea? No, not the Atlantic Ocean. This geography of millions of years ago may be pictured if we imagine the Gulf of Mexico, Hudson Bay and the Gulf of St. Lawrence to be extended mutually toward each other until they meet somewhere in the Central States. Then let these salt waters spread widely, and they will produce a vast, shallow, inland sea larger than anything of its kind now on earth, but representing a condition not uncommon ages ago. The eastern shore crossed Pennsylvania in a southwesterly direction; and, eastward therefrom, none knows how far, stretched a land which geologists have christened Appalachia. It must have occupied much of that region of the globe over which to-day spread the waters of the western Atlantic. Every one knows that the rivers of eastern Pennsylvania flow eastward or southeastward toward the ocean. The rivers of Appalachia ran westward into the inland sea. Their direction was essentially the opposite of our Delaware, Schuylkill and Susquehanna. Laden with waste washed from the land, they carried their burdens into the ancient, Mediterranean-like body of water and there laid them down as sheets of mud, gravel and sand spread far over the old sea floor.

Our solid rocks to-day are the hardened remnants of those very sheets. In them we trace here and there the ancient shore-line with its sandy beaches and spits, its gravel banks, rippled sand-bars and muddy estuaries. Or, we may discover an ancient delta where some now extinct river left its load of ground-up rock brought down from an inland mountain chain. Farther out from the old shore-line, we find the remnant of ancient coral reefs where it bordered sheltered lagoons. Suppose, in imagination, we exchange our hammer for a deep-sea dredge such as is used for collecting samples of mud from the ocean bottom. To complete the illusion, let the family "flivver" in which we have gone fossil-hunting become a sea-going tug. Then may our rock specimens be likened to mud samples from the ancient sea bottom. Farther and farther from shore we cruise. Now our dredge brings up black mud, the antecedent of our slates, and again it drips limy ooze which we recognize to-day hardened into one of our many limestone formations.

But, did all our rocks originate on the sea bottom only? No, not all of them. Those vast deposits of coal and associated shales and sandstones filled with plant impressions which make up the dominant rocks of our coal fields are of no deep-sea origin. These are the hardened gravels, muds, sands and matted accumulations of dead plants which formed in river beds or on their flood plains, in piedmont regions and along low, swampy, coastal flats. No one need be told that the salt sea which once covered so much of the interior of our continent is no longer there. Part of the explanation for its disappearance is to be found in the fact that the sea was finally filled, at least along the borders, with the sediments the rivers brought in or the waste which storm waves tore loose from the coast and currents dragged out to sea. Where the sea was filled, coal-bearing rocks and other formations of non-oceanic or fresh-water origin (called "continental deposits" by geologists) came into being.

"But," you comment, "this may be instructive to some, but so far I have waded through several pages of an uninteresting recitation of dull statements about ancient and literally long-buried topics. I am as incredulous as was your 'gas' station attendant, and echo the Mock Turtle with, 'What is the use of repeating all that stuff, if you don't explain it as you go on? It's by far the most confusing thing *I* ever heard!' "

May I, without offense, presume to paraphrase so far as to say, "By their fossils ye shall know them"? There is the key explanation of most of our deductions. First, of course, we do examine the character of the rocks themselves. That tells us much. Dissolve away the material which holds together the pebbles in this piece of conglomerate or "pudding stone." What remains? Gravel, to be sure. Do the same with this sandstone; the answer is, sand. Could we likewise soften a specimen of shale, the result would be mud. Who has not seen gravel, sand or mud accumulating in half a dozen different places and under as many unlike conditions? Can you not from this hazard a guess as to how these rocks came to be? And now suppose that they contain fossils. We have a much better means of discovering their origin. Our ancient sea was populated by myriads of "shell fish" whose forms and habits are comparable to the forms and habits of their living descendants. As in the seas to-day, so in the waters of long ago, some animals lived in the shallows, some in the deeps, some near to, others remote from the coast.

Different forms inhabited the beach, the tidal marsh or the lagoon. Many animals spent their lives anchored in one spot, and there were those which crawled on the ocean bottom. More passed their days burrowing in the ooze and mud. Still other forms swam gracefully about or drifted helplessly, carried by wind or current. By analogy with to-day's marine population, we deduce the habits and hence the surroundings of the animals whose fossil remains we see in the rocks of Pennsylvania.

Likewise, or conversely, our fossil land plants show not merely that the associated coal beds formed on land, but give a clue to the ancient climate. Plants have been called "the thermometers of the past." Unlike animals, they can not move about and escape unfavorable climates; they must learn to live under new conditions or perish. Consequently, the characteristic plants found fossil imply something as to the temperature and moisture of the ancient climate amidst which they flourished.

So we obtain from our fossils an inkling of the conditions under which the rocks that imprison them were formed. Be the enclosed remains those of deep-sea dwellers, the rock originated far from land, but if the fossils are only land plants, quite the reverse is true. But, suppose a rock contains a mixture of leaves and sea shells? We may assume its origin to have been in the sea but near shore where a river brought plant débris down to become waterlogged, sink to the bottom and be buried with the remains of sea life.

Such relations as these may be studied in Pennsylvania's rocks. Generally speaking, if one starts in the southeastern corner of the state and goes north or northwest into the nearest coal fields, he passes, with few exceptions, over a series of rock formations which lie successively one above another, that is, the farther we go, the younger are the rocks which we cross. The difference in ages of the extremes of this rock series is reckoned in hundreds of millions of years. Therefore, we are not surprised to find that the fossils in the rocks change as we go from formation to formation. Each is characterized by its own, individual sorts of fossils or groups of fossils common to no other formation. Organic evolution was constantly changing the character of the population, and each group of rocks carries a different cross-section of the evolutionary stage fashionable at the time it was laid down. The fossils are convenient earmarks by which we separate and recognize the several formations wherever we meet them. As we pass from older to younger beds, a profound life-change is seen. Our oldest fossiliferous rocks have, as their highest type of animals, certain "submarine vermin," small crustaceans no more to be reckoned with than so many good-sized shrimp. But, as we rise in the rock scale, and simultaneously scramble up the ancestral tree, we may be surprised to discover the bony armor which once protected the body of an ancient fish-like form. With this discovery we have reached the rocks which formed at the beginning of the age of backboned animals. If we go still higher in the scale of rocks and life, we (at least in Pennsylvania) turn to our coal deposits and those other related rocks which formed in later days, not in the sea, but on land. In them we encounter "bigger and better" fossils. The plant-bearing shales of the coal measures are occasionally dimpled with little foot tracks; foot tracks of crawling, creeping, salamander- or lizard-like folk. Here are forms above the fishes, but still "far down in the animal scale" as we complacently say in self-adulation. The many leaves and stems found with them, and the ancient tree roots embedded in soil now changed to solid rock show where the original "Penn's Woods" raised its green crown toward the sun. Now and then, though very rarely, for they are extraordinarily delicate fossils, we may find among our coal plants a "leaf" more curiously veined than all the rest. That "leaf" is actually a wing! Not the feathered wing of a bird, for birds were not "invented" then, but the wing of a large, primitive insect which bumbled its clumsy, leaf-eating course among the old, flowerless plants or delighted to tickle the noses of the "creeping things" in swamps where coal was a-making.

The coal-time plants and animals are very ancient. And yet, though they lived some hundreds of millions of years ago, theirs is the last well-recorded chapter of earth history to be read within our borders. Father Time writes his record on stony pages; the characters which flow from his never-failing pen are the fossils. But, many pages, whole chapters or volumes, may be missing. So, if we would read all the rest of the story and understand what happened since the coal was formed down to to-day, we must roam far abroad from Pennsylvania to where a more complete record is preserved. But we have been permitted to take at least two glimpses of some of the later pages of Time's book, pages which that devastator, Erosion, has not ripped out and tossed away from the state's rock library.

The broad band of red sandstones and shales which runs from Gettysburg northeastward to the Delaware Valley preserves, though in a sadly fragmentary state, part of a chapter taken from that volume of earth history on whose title page is written "The Age of Reptiles." In these rocks one now and then finds a curious three-toed foot mark some three or four inches long. Occasionally, a row of these shows where an ancient Pennsylvanian picked his way across the mud flat of a now long forgotten river. Would that it were possible to take up the trail, track down and capture at least his fossilized skeleton! But, in Pennsylvania, a few bits of broken bones and stray teeth are all that these red rocks have yielded of the track-makers. They are, nevertheless, recognized as remnants of that surprisingly dull-witted and usually, perhaps appropriately, greatly oversized group of reptiles, the dinosaurs. It is an age-long gap from their time back to the period of coal-forming, but it is a far greater interval from the days of the dinosaur to the last chapter in Pennsylvania's record of earth history.

Thousands of years ago, a very short time compared to the hundreds of millions of years during which the earth has been circling about the sun, North America was in the grip of the Great Ice Age. Then a greater part of Europe and North America became temporarily ice-buried, just as is Greenland to-day. But, despite the chilling, "normal times" eventually returned, and events jogged on as usual. Now, this great ice-forming epoch happened such a short time ago that much of its record is still intact, unspoiled by time, so that we fancy we know a vast deal about it. Over much of the northern half of the State of Pennsylvania, there ground its way southward a giant ice sheet. Slowly it advanced from its far northern base of supply. Then for a time it melted back again, perhaps into Canada, advanced at least once more, melted again and finally disappeared altogether. Naturally, with all this uncertainty of purpose on the part of the ice, the equability of the climate suffered terribly. When the glacier advanced, the weather was so abominably cold that the musk ox trotted down into the Southern States and the walrus lolled on our Atlantic beaches. But, sometimes when the ice drew back, the climate improved remarkably, growing milder than that of to-day. Then, such southern forms as the peccary and jaguar ranged north into regions to which, outside of "zoos" and circuses, they are to-day strangers. Here, again, fossils enter the story.

Because the ice never came quite as far south as the latitude of Reading, we have beyond its southern border an unglaciated country where contemporaneous animals and plants then living in Pennsylvania could leave their fossil remains. Can you imagine elephant-like creatures munching the foliage in Chester County? It is true that the mastodon and other even stranger beasts roamed unrestricted where now our domestic animals graze. Over half of the forms found fossil from the glacial time are probably now extinct; many others are to-day represented only in far-off lands by surviving descendants. They are gone from their former haunts in the Juniata Valley. No longer do they make winter quarters about Valley Forge as once they did, long before the advent of the Continental Army. In caves or crevices in the rocks have been found remains of mastodons, giant sloths, saber-toothed tigers, huge bears, a host of smaller beasts, a few birds and many kinds of leaves. Perhaps these write the last paragraph in the closing chapter of earth history recorded by fossils in Pennsylvania. Yet there is a possibility that we may add still another sentence; or only just a footnote. Perhaps you are asking, "What about man?"

Our answer is, "Wait and see." We are not sure. There are doubtless tons of arrowheads, corn grinders, net sinkers, clay pots and tobacco pipes of aboriginal manufacture accumulating dust in our museums and attics or proudly displayed on center tables or in "whatnots." But they are all brand new objects and no more traces of fossil man than King Tut's mummy, Westminster Abbey or William Penn's house. They are not prehistoric, but were made by the same race of "red" men whom our ancestors found here making appropriate to the American wilderness the adjective howling. Fossil man has long been known in Europe. Recently, evidence of his presence in parts of North America has begun to amass. In the West, certain flint "points" of peculiar design unlike any known to have been made by the Indians have been found mingled with bones of extinct mammals. But, disregarding our own venerated though largely discredited Lenapé Stone, we have no very sure evidence of the occurrence of pre-Columbian man in Pennsylvania. Some day, perhaps, a farmer will walk into my office or some other luckier fellow's office, with one or a bushel of these curious flints, and when he does, we can add at least this item to our history of fossils in the state. Even lacking such a final bit of proof and allowing for all the gaps in our rock record, is there not enough in what we do have to furnish "a source of innocent merriment"? Have we not here the means of profitable amusement, if not real research, for those who will inquire about the fossils of the state in which they live? Here, indeed, should be entertainment for those who care to ask themselves and others, questions about our rocks, their contents and their history.

THE STOMACH AS AN ORGAN OF SOCIAL ADJUSTMENT

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In that new biography of Joseph Conrad, written by his incredibly patient wife, there is the record of a visit by H. G. Wells and Bernard Shaw. Wells, Mrs. Conrad remembers, had a headache and would eat nothing but a slice of dry bread, washed down by a glass of quinine water, while Mr. Shaw made his meal off a cup of cocoa and a dry biscuit. Genius doubtless, like an army, travels on its stomach, but what a stomach!

The reason that we stand in awe of the stomach is that this organ, more than any other of the viscera, controls our social adjustment. Many years ago the wisdom which directs our medical school ordained that lectures in anatomy shall be given either at 8 : 30 in the morning or at 1 : 30 in the afternoon. At either of these times it is evident to the discerning and sympathetic teacher that all is not well with his charges. Their spirit doubtless is willing, but their flesh is very weak. Hence, some twelve years ago, Miss Kuenzel and I set ourselves to investigate the natural history of the stomach, hoping eventually to draw up some schedule of its habits in work and play, its moods and eccentricities. We did not care particularly about the stomach of animals nor even about the stomach of the sick. We were content to leave the elaboration of first principles to the physiologists and the discernment of disease to the clinicians, though we had some curiosity as to why the dim grey light of a February dawn, made famous in history by the execution of Mary Queen of Scots, should have so intensely depressing an influence on the human race and why the early Christian Fathers originated Lent. Our attention in the main was fixed on just what goes on in the secret recesses behind the rows of vests confronting us with more or less bombast every early morning and every early afternoon through eight months in the year which end with examinations scheduled, by some pedagogical demon now forgotten, in the very time of year when, from the nature of the season, young love might reasonably be expected to have least stomach for them.

In the course of time we did indeed draw up a modest tract which, if it did not satisfy the appetite of grim unhumorous scientists, did at least tickle their risibility. We gave it the title "Behavior Patterns of the Alimentary Tract." But even in 1930, when that volume appeared, the idea of behavior patterns in the stomach seemed preposterous to almost every scientific mind. Slowly, however, it has come to be realized that the stomach does have registrable moods and method in its manner of working, a knowledge of which contributes not a little to the brightness of life.

The stomach is a muscular organ, the activity of which is expressed in rhythmic waves of contraction which pass along it analogous to those waves of contraction which pass over the heart and are known as the heart beats. Waves of gastric contraction are called peristalsis and their rate is much slower than the rate of the heart beat. But inasmuch as the heart beats force the contained blood onwards into the blood vessels it has been assumed that peristalsis of the stomach occurs for the purpose of forcing onward the gastric contents. Furthermore, on this hypothesis, it has also been assumed that the activity of the stomach would be greatest during and after a meal and that between meals the stomach would be at rest. Another simple notion about the stomach is that it secretes an acid digestive fluid for the sole purpose of starting digestion in the food, which later is propelled into the intestine by the peristaltic waves.

No one had actually seen the stomach at work until the invention of x-rays, which permit us to look through the body and watch the activity of the internal organs. It is true that the stomach had been watched during abdominal operations, but something interferes with its activity in these highly abnormal conditions so that movement is reduced to a minimum. It is also true that gastric activity had been observed in experiments on animals, but again this involved opening the abdomen and disturbing the conditions under which the stomach normally operates.

By mixing with the food a substance opaque to the x-rays and without influence on gastric activity, barium sulphate being usually used for this purpose, one can now easily study the movements of the stomach and, what is more surprising, watch also the accumulation of gastric juice within the organ.

This procedure is regularly carried on in the hospital to enable the clinician to observe the shape, size and movement of the stomach, but inasmuch as healthy people do not usually go to hospital the study there is almost always made on diseased or functionally disordered stomachs. It was not till Miss Kuenzel and I, with the active assistance of our medical students, undertook the routine systematic study of gastric activity, that this investigation of healthy stomachs was carried out on a scale large enough to justify conclusions on what actually takes place in the stomach free from disturbances of form or function. More than 800 medical students have assisted us in this work, so that the detailed study of their stomachs, added to the two which Miss Kuenzel and I possess in our own right, a study which has been prolonged for hours at a time and continued day after day at all seasons of the year, enables us to speak with confidence concerning this shy and somewhat irresolute organ.

When we first began to examine the student stomach eleven years ago we were impressed by two features, namely, its large size and its inactivity. Of course we did not realize that we were dealing with stomachs unused to being spied upon in this manner. We started the work at the beginning of the session in September, 1925. By February of the next year we began to realize that these stomachs which, in September, were so large and sulky were now smaller, even though we gave exactly the same amount of food as before, and more active than we had found them earlier in the session. By the following September these same stomachs had greatly stepped up their activity and they were very much smaller than we found them the previous February. But by this time we had a new set of stomachs to contrast with those we had been observing for a year, namely the stomachs of the incoming freshmen. These stomachs behaved precisely like those of freshmen of the previous year. They were very large and very sluggish, but in the course of the session they also cheered up, grew smaller and became more active.

In time it dawned on us that we were dealing with an organ very susceptible to emotional influence and that the apprehension and bewilderment of the freshmen at this new method, for new it was at that date, of learning anatomy, enhanced by the lurid suggestions of upper classmen, so played upon their stomachs that they froze with fright. We did not care to call it fright, so we dubbed it disquiet. When confidence has been restored to the subject of investigation his stomach movement is revived.

So far so good. We had interpreted satisfactorily the initial inactivity of the stomach, but we had still several years of study ahead before we realized the explanation of the large size. One of our collaborating students with a taste for mathematics, Dr. W. A. Sommerfield, devised an ingenious method of estimating the volume of the stomach from the measurements of the x-ray shadow. By this quite reliable technique he was able to assure us that even though we gave only 4 ounces of fluid to a student on a stomach previously demonstrated empty, that stomach contained in less than five minutes not simply the fluid swallowed but an additional amount of fluid, which varied with the type of food swallowed. We had already noted that the stomach was much larger after giving 4 ounces of buttermilk than it was after giving 4 ounces of milk. Within 5 minutes after this quantity of milk is swallowed the stomach contains approximately 12 ounces of fluid, but after the same quantity of buttermilk it may contain 20 to 30 ounces. We then realized that gastric juice is secreted to an amount which varies with the type of food swallowed. But Dr. Sommerfield showed that these figures hold only for the stomach in a state of disquiet. The unruffled stomach does not contain nearly that amount of gastric juice. It is obviously preposterous that the stomach should secrete more juice if the subject is in an apprehensive frame of mind. Something must have occurred to bank up the secretion in the stomach. Hence we turned our attention to the pylorus or outlet of the stomach, the passage from stomach to duodenum or first part of the intestine, where there is a thick muscular belt surrounding the orifice. We watched this outlet narrowly and found that in disquiet stomachs it remains closed for a long time after food is swallowed, whereas in the stomachs of students well accustomed to the investigation it permits passage of contents within two minutes. We had now found the explanation for the large size of disquiet stomachs. The size of the organ depends less upon the amount of food taken than upon the relation between gastric juice secreted and the passage of contents through the pylorus.

Emotional states reduced the peristaltic activity and at the same time caused prolonged closure of the outlet.

If this interpretation be correct we should of course lose what we called the typical freshman gastric pattern as incoming students become more accustomed to the idea of being studied. This indeed is precisely what has happened. The freshman pattern of 1925 no longer exists in 1936. Freshmen of the current session have far more active stomachs than sophomores of 1926, and moreover at the very first examination we are able to demonstrate passage of contents through the pylorus within 2 minutes after swallowing food. But on the day of an examination or under conditions of mental stress the student's stomach once more relapses into the behavior pattern of the freshmen of 1925.

Our first lesson in the study of gastric behavior then is its susceptibility to disturbance of emotional origin. That disturbance is elicited by mental stress of any kind, by incipient illness, by hurry or by physical fatigue. The unwisdom of eating much before hurrying for a train, entering an examination, attending a board meeting where trouble is brewing, when feeling ill or physically exhausted is explained in objective terms. The pylorus closes. Contents are banked up in the stomach, the organ remains awash and the sensation of heaviness, distention and acid risings result from impaired motor function.

Some stomachs are much more prone than others to this disturbance of function, the chief site of which is to be found in the pylorus. Moreover, the disturbance is apt to ensue from certain specific foods. These act as a trigger mechanism, inducing closure of the pylorus in a sensitive stomach. If the reaction is very vigorous, vomiting will ensue as nature's method of relief. If, however, the response is less pronounced the victim continues for a considerable time in a state of gastric discomfort until the pylorus opens of itself or is tricked into opening by the administration of soda or some other medicine like belladonna or amyl nitrite or by a drug which used regularly to form part of the gastric "sedative," namely, dilute prussic acid.

A victim of this disturbed gastric function experiences much more than mere distension. He may have pain and severe tenderness in the upper abdomen. Often he shows drowsiness, mental inefficiency and a tendency to abstraction or daydreams. His temper may wear thin; he becomes irritable or he may have a prolonged bout of sneezing and congestion in the head. Curiously enough, the pylorus may be opened by a good sneezing fit. There is an excellent digestive in pepper or in the snuff-mull which our ancestors handed round with the port after dinner.

Vincent of Beauvais in 1250 A.D. extolled the virtues of cinnamon and pepper in curing disturbances of the stomach. It would be interesting to follow those irritable people of long ago who relieved their pent-up feelings and fulfilled their wild imagination by indulging in the spice wars to obtain those condiments so necessary for the comfort of their overworn stomachs.

Evidently we must glance at the reverse side of the picture, namely, the influence of the stomach on the mind. Samuel Johnson is a good example. His attack of nervous depression in 1766 was certainly of gastric origin. At any rate Boswell's "Life" abounds in references to the influence of the stomach, which was constantly and acutely bringing itself to the doctor's attention. There is no doubt at all of Johnson's chronic indigestion with which often goes a brilliance of imagery and creative thought. Benedick's "quick wit and queasy stomach" remind us of the indebtedness of both literature and science to indigestion. Would Darwin have framed the theory of evolution had it not been for the imagery created by his chronic indigestion? Would Conrad have written his stories had the facts of his experience not been sharpened and amplified by nervous dyspepsia? How much of Poe's tales of mystery and imagination were due to indigestion and how much to alcohol. It is so easy to ascribe to a drug the very talents which were in fact merely disordered by indulgence. For this attitude perhaps De Quincey's "Confessions" are most to blame. He thrust upon us the suggestion of association from which commentators and critics have never been able to free themselves.

Did Francis Thompson write "The Hound of Heaven" under the influence of opium or was it really his dyspepsia which "set the winds of inspiration blowing"? Could Coleridge's "Ancient Mariner" really be due to indulgence in "the milk of paradise" which distorts the mental vision or was it actually a vivid drama from a keen and orderly imagination?

There is a paragraph in the biography of George Crabbe, quoted by Abrams in his recent essay to confirm the theory that morphia was responsible for Crabbe's inspiration. After Crabbe had experienced a fainting spell in 1790 a certain Dr. Club was called, who "saw through the case with great judgment." "Let the digestive organs bear the whole blame; you must take opiates." Abrams may be right, but it seems to me far more reasonable to link Crabbe's genius with his constitution than with a poppy. The tumult and terrors of opium torment the imagination; they do not clarify it.

So often we impute to violence the authorship of the momentous things in life. Restlessness intrigues us, but restlessness is not progress. Somewhere in Horace there is a sentence which calls to mind the fact that those who cross the sea change only their climate and not their minds. True progress is measured not by pushing ever wider the boundaries of human effort but by deepening the fellowship of the spirit.

Perhaps it is pointless to pursue this argument. Better leave it incomplete and return to the main theme. Certainly some folk sparkle with wit about the dinner table when others at the same meal drop off into somnolence, and one man's meat is another man's poison. One thing at least is certain. It is not from the torpidity of semi-poisoning or the disordered mentality induced by drugs that brilliance flows, whatever may take place in lucid intervals.

It took years of observation to make us realize that the phenomena we were observing in the activity of the stomach depend not alone on the state of mind but on the specific reaction of the stomach to what we put into it. Some people can not drink milk without disturbing their digestion. To others buttermilk is nauseating. There are those who dare not touch an egg, who get a rash from strawberries or break out in hives from what they call "over-heating" foods. Just what goes on in the stomach when a food to which one is sensitive is swallowed we do not know. But some mechanism is set in action which, as part of its manifestation, closes the pylorus firmly, just as emotion does. There is no doubt that the abdominal distention and discomfort which follow, in some people, the eating of certain foods, results from closure of the pylorus and banking up of contents which are greatly increased by the flow of gastric juice.

Of course this gastric juice really is elaborated from the blood, and fluid secreted in the stomach is actually withdrawn from the blood. Were there not a return flow to the blood stream by way of absorption from the bowel we should quickly become as dry as a mummy. But of this internal water circulation scarcely anything is yet known. By means of the x-ray we can watch the banking up of fluid in the stomach and its release when once again the pylorus is opened to permit its passage.

So now we come to the question of what makes stomach contents pass into the duodenum. It is a rather arresting fact that, whereas saliva flows when we chew solid food but not when liquids are taken, gastric juice can be seen to pour into the stomach far more freely when liquid nourishment is swallowed. The device is obviously a flushing of the fluid through the stomach by the outpouring gastric juice. When solid food is swallowed peristalsis does act to some extent in passing it onwards, though the relatively small amount of gastric juice then secreted plays its part as a flushing agent. Whatever the food swallowed, liquid or solid, provided there is no emotional barrier and the stomach is not "sensitive" to the particular food swallowed, passage into the duodenum can be observed to commence within two minutes. It is certain then that the long periods during which some foods are known to remain in the stomach merely indicate a sensitivity in that person to that food. None of the 800 medical students whom we have investigated, unless his stomach has this disability, has ever been able to command a breakfast or a lunch which remains in the stomach more than an hour and a half. The popular notion that some foods remain longer in the stomach than others must be based, not on the healthy activity of the stomach, but upon a disordered function due either to emotional influence or constitutional sensitivity registered in advance in dislike or in retrospect in discomfort.

The conditions of our daily life formulate for us, did we but know it, the limitations of our dietary and the artistry of its application. For the stomach is a self-respecting organ which resents rough handling and manifests its disapproval by local signs. If these are disregarded it dislocates the mechanism of the body, touches the mind and casts dismay into the spirit. The stomach may well be characterized as the organ of social adjustment. In it are reflected, as from it flow, the social blights or blessings of the time.

YOU CAN'T TRAIN THE INTELLECT BEFORE IT ARRIVES

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Of all the psychological gold bricks ever foisted upon a gullible public, there are few that can match the one which claims to make your baby into an intellectual giant by the right sort of training administered in the cradle. Here is the claim, or at least a part of it, presented as a study in black and white.

> There is no such thing as inheritance of capacity, talent, temperament, mental constitution and characteristics. These things depend on training that goes on mainly in the cradle. . . . Give me a dozen healthy infants, well-formed, and my own specified world to bring them up in, and I'll guarantee to take any one at random and train him to become any type of specialist I may select—a doctor, lawyer, artist, merchant-chief and, yes even beggar-man and thief, regardless of his talents, penchants, tendencies, abilities, vocations and race of his ancestors.

There would be millions in it in tuition fees for any one who could fulfil this promise, but one hears of no stampede to open the necessary nursery schools to turn out the product. There might, however, be something less desirable than millions as the net result if the claim turned out to yield fool's gold rather than the genuine article. The claim appears to be widely accepted outside of professional educational circles, but this acceptance seems to be for academic and theoretical purposes only. It is possible, too, that there is, tucked away in the inner recesses of the unconscious, a complex left over from earlier mental conflicts, to the effect that all is not gold that glitters. And this seems to be effective even in spite of the wishful thinking which might tend to create an attitude favorable to acceptance of the alluring claim; for what fond dad is there but is willing to believe his very own infant capable of attaining to anything from Caruso to President, if only supplied with the opportunity that, unfortunately for the rest of the world, was denied to his dad?

II

But what problem is there which should be of greater concern than the possibilities of human development? And why should not at least as much care and consideration be given to it as to the possibilities of improving automobile construction? As a parent one is and ought to be concerned as to the means by which his children may develop to best advantage. What are the possibilities at each stage of development—infancy, childhood, adolescence, adulthood? What are the phases of development which are attainable at successive ages? What are the limits, if any, to the mentality, the personal and social assets which may ultimately be developed by any given individual? These are questions worthy of the most careful investigation by the most competent scientists available.

For the professional educator, whether in the capacity of teacher, superintendent, university professor or United States Commissioner of Education, the problems of possibilities and limitations of learning and development loom large in significance. One's beliefs on such things largely shape his educational policies, and therefore it is important that those beliefs should be founded upon fact and not upon wishful thinking nor upon unwarranted claims.

Nor is the situation different in the

case of the would-be philanthropist who seeks to lessen the human distress and the tremendous economic waste involved as direct and indirect results of feeble-mindedness, degeneracy and crime. What can be done about it? Will slum clearance reform a community? Is it the physical structure which determines the quality of the home, or is it the character of the people in it? Will improved educational facilities abolish crime and dependency in normal times? These problems are of vital significance to all parties concerned.

When an influential educator confronts a superior group of young people, how tempting it is for him to claim them as the product of the schools whose interests he is fostering. But how about the morons and the delinquents and the incurably shiftless who are also the product of the same educational system? One could wish that every influential citizen were familiar with the outstanding problem which confronts our schools—the problem of individual differences. Visit a class of the intellectually subnormal, and then visit one of the major-work classes for the intellectually gifted in our city schools, and you will get a picture that will not soon be forgotten. The contrast to the uninitiated is astounding. Nor does the matter become any simpler when one realizes that some of the most capable principals and many of the most competent teachers are to be found in the schools where the educational product is the most deplorable. The fact of the matter is that the educational facilities in a large cosmopolitan city, in the way of equipment and teacher personnel, do not vary greatly from one school to another. They play no favorites in a large city school system, but provide as best they may the educational opportunities most suitable to all. In fact, until recent years the schools attempted unwisely to provide *the same* opportunities for all.

When the farmer has drained the swampy places in a field and fertilized the barren spots till all parts are nearly on a par in productivity as a result of improved nurture, it is not variation in the cultivation that is responsible for the wide range of the product—potatoes, cabbage, ragweed, little wild strawberries, large luscious strawberries, maple trees, red roses, dandelions or what not. One does not grow figs from thistles. A horseman does not attempt to produce a race horse from a Clydesdale colt by any miracle of early training. He believes that whatever of training skill he has will be expended to better advantage if he selects a colt of race-horse heredity upon which to expend it.

And if the farmer wishes to restrict his planting to one species of product, say strawberries, he gives careful attention to the matter of heredity in his planting He does not plant any and all vines that happen to be strawberry vines. On the contrary, he practices eugenic principles shamelessly. He eliminates the poor little sour strawberries altogether and plants only those vines which have the finest heredity. On this basis he predicts large, fine-flavored berries with comparatively little variation in the product, and he gets them. He believes in having his fruit well born. He is not sentimental about it, because it is the quality of the product with which he is concerned. He does not save even a random sampling of the poor little sour strawberries. With the quality of the soil remaining constant, and the cultivation unchanged, he has greatly restricted the range of his product and improved the quality permanently, merely by giving attention to the heredity factor—the seed planted.

III

One who studies the situation in the schools of one of the large cities will find a greater range of product in a single school than could be found on a farm where no attention was given to selection of the seed to be planted. Some farmers still grow many small potatoes as well as large ones, and it takes more small potatoes to make a bushel than if the potatoes are large. But how many morons does it take to make a genius? Rather, what proportion of the energies of the genius must be spent to help provide for the moron? Morons as a class are a heavy liability. It is doubtless true, however, that the large majority of people, including some in professional circles, accept in theory the belief that it is the nature of the environment which largely determines the kind of person produced. This view is the one which fits in well with convenient interpretations of democracy. It is well voiced by Wat Tyler, who led the Peasants' Revolt in the reign of Richard II in England:

> When Adam delved and Eve span,
> Who then was the gentleman?

People who were born into a feudal system of society were seriously and unjustly handicapped thereby. Those who have no opportunity to learn to read or to write are largely shut out from contact with the intellectual inheritance of the ages. They are seriously curtailed in the development of the hereditary abilities which were potentially theirs. But that is not the story here under consideration. There are not to-day the wide differences in educational opportunity which characterized the Middle Ages. In a large modern city, elementary and secondary schooling are provided for all. Indeed the law requires all to attend school until they are sixteen or eighteen, so that each may get whatever his abilities enable him to get.

But the phase of Tyler's rhyme which is of interest in this connection is its implication that descendants of the same remote ancestors, members of the same species, are equal in their possibilities of learning and development. I am reminded of the moron who gave a welcoming hand to his former schoolmate in the village school, who had just returned home as a newly graduated M.D. "Jim, ye looks swell," grinned the moron. "I wish now I'd 'a stuck to school like you done. Jist see where I'd 'a been to-day 'stead 'a hoein' turnips."

In my judgment there is no implication in the whole realm of educational theory which is more fundamental than this. If one infant can be educated to become as able and as worthy a citizen as any other infant, then why under heaven do we tolerate an educational system which regularly develops one or two per cent. into morons or lower, one or two per cent. into highly gifted intellects, and the rest into varying degrees of mediocrity? Why does this distribution of human abilities correspond so closely to a normal probability curve, to which so many things in the biological world conform in their distribution of individual differences? If the production of Newtons and Edisons and George Washingtons depends on training which goes on mainly in the cradle, then why doesn't some one bring back the cradle! Most experienced teachers of unselected school children know the answer to this question as a result of their experience. Experts in educational psychology know the answer given by well-controlled scientific experiments carried out within the past few years. The evidence is there for those who have the time and the energy to dig it out. We shall come to it presently, but first the historical background of the commonly accepted view deserves consideration.

IV

Whatever may have been the influence of such men as Wat Tyler, Rousseau and would-be philanthropists from time to time who have tried to eliminate the criminal, the moron or the irresponsible incompetent by some utopian plan of education, it was the English philosopher of the seventeenth century, John Locke, who was mostly influential for at least two centuries in shaping the opinion in the universities with regard to the value of mental training. Locke took what seemed superficially to be self-evident, made it articulate and gave it the weight of scholastic authority. Who has not noticed that the right arm of the blacksmith becomes strong by exercise? What observant man of the eighteenth or nineteenth century could fail to see that it was, for the most part at least, the men who took classics and mathematics in the universities who became the most accomplished intellects of the age? Was it not the exercise required in mastering those difficult subjects which made them intellectually strong? Up to the beginning of the present century it was unquestioned educational theory that it was the mental stunts practiced in college which increased the power of the mind as a whole, or increased the power of more specific faculties of the mind such as the memory, the judgment, the reasoning powers and the imagination.

But at the beginning of the present century, this disciplinary theory of education received a shock at the hands of a pair of young psychologists from which it never recovered. When tested experimentally by Thorndike and Woodworth in 1901, it was found that mental exercise did not improve the mind as a whole, nor even the more specific faculties in any such wholesale fashion as the old disciplinary theory of education had assumed. A new educational psychology was in the making. Mentality was put into the crucible. The battle waxed hot. But all along the line opinion and the armchair philosophy of the old school had to give way before the experimental evidence presented by the new school, which demanded the right to examine the basis for the assumptions of the past. Things began to happen in several different fields closely related to educational theory and practice. The school administrator began to press seriously for an accounting of the expenditure of school funds in terms of educational product. Why were many children retarded a year, others two years and still others three or more years, in the very same schools in which other children did the expected requirement of one grade per year without loss of time? The waste of the taxpayers' money as a result of retardation in the schools was put into the limelight and laid upon the doorstep of the educational psychologist for solution. Why shouldn't all progress at the same rate when they had the same teachers?

The problem was just as insistent in the schools of Paris as it was in the schools of American cities and, as it happened, Alfred Binet, working under the stimulation of the school board of the city of Paris, was the first to offer an answer that was reasonably convincing. His means of demonstration was the Binet scale for the objective measurement of intelligence. His answer was that children vary enormously in their inherent capacities for learning and that such differences must largely determine the rate of learning to be expected. Moreover, it appeared that individual differences in ability to learn were highly stable as well as wide in range and that they must be taken into account in all educational policy.

Meanwhile Terman, Thorndike, Norsworthy and others had been working on the same problem, and were precisely in line with the findings of Binet, and all set to profit very rapidly from his stroke of genius in putting the results of many years of experimentation with intelligence testing into workable form. Under the leadership of Thorndike, tests for the objective measurement of school achievement began to be constructed in accordance with the best-known statistical principles. Once the pattern was set and the matter given national publicity, the construction and use of such tests progressed by leaps and bounds. Experimentation in school problems by the aid of these new tools for measurement of mental ability and of school achievement proceeded with surprising rapidity. In fact, the growth was somewhat too rapid for the good of the cause, although the leaders made every effort to put on the brakes and to keep the movement within due bounds. By and large, however, the general upshot has been the most notable advance within the last quarter of a century that has ever been recorded in the history of education in a like period of time. The advancement, particularly in the last five years, has been tremendous, and it has included very important work on the heredity-environment problem.

It took a Darwin to make it clear that man is an animal in every sense of the word and, as such, subject to the same biological laws of heredity and environment as other forms of plant and animal life. The first man of genius to investigate the laws of inheritance in plants was an Austrian monk named Mendel. Mendelian principles of heredity remained practically unnoticed for three decades, but finally came into their own about 1900. The science of genetics, which seeks to unravel the laws of inheritance in plants and animals, has developed with great rapidity, especially since 1915. It is impossible to summarize the findings of a whole new science in a few words. However, some of the incontestable facts brought to light are that the wide range and the distribution of the differences found within a species under ordinary conditions are to be explained in terms of differences in heredity—differences in the chemical packets called chromosomes which are contained in the fertilized seed or egg from which the plant or animal developed. These chromosomes are paired, one member of the pair always being supplied by the female egg-cell, and the other member by the male sperm-cell which fertilized it. The male sperm-cell in man is so small that it requires a high-powered microscope to see it. It is made up almost exclusively of twenty-four chromosomes. One of these chromosomes contains the factor which determines the sex of the individual to be. The progeny on the whole resembles the father as much as it does the mother. And yet this sperm-cell, microscopic as it is in size, is absolutely unique in the chemical packets it contains. It has thrown away exactly half of those which made up the inherited constitution of the father, and has kept a combination as unique as the hand one receives in a deal in bridge. Moreover, the resulting combination of chromosomes is the result of a chance shuffle, just as the hand of cards is due to chance arrangement determined by the shuffling of the pack of cards. The same is true of the egg-cell which likewise becomes half of the inherited constitution of the new individual.

Thus genetics explains why it is that two brothers never have the same hereditary constitution and why so-called "identical twins" do have the same or nearly the same hereditary constitution. Identical twins are descended from a single fertilized egg which has split into two, while two brothers are descended from two different eggs, each having its own individual combination of chromosomes. On the whole, children resemble their parents to an extent indicated by a coefficient of .50, where a coefficient of one would represent identity, and a coefficient of zero would represent no greater likeness than in people of no blood relationship.

The significance of all this for educational theory lies in the fact that individual differences in inherent nature are to be expected, even in the case of children of the same parents, and that incomparably greater differences are to be expected in the children of parents who vary widely in hereditary endowment. With minor exceptions due to special causes such as injury occasioned at birth, the difference between the genius and the moron is to be accounted for in the main by differences in hereditary constitution.

VI

But meanwhile there have been other influences on the educational horizon which have made the situation difficult to evaluate, particularly for the non-professional. First came Freud with his cases of emotional complex which he explained as the result of early experiences, often long since forgotten in the ordinary sense of the word. And if such experiences upon investigation turned out to be inadequate to explain the mental disorder, Freud was not disconcerted thereby. On the contrary, he merely sought the causes in still earlier experiences in babyhood or infancy. One sometimes suspects a case of retreating to still more inaccessible strongholds as the original ramparts become untenable. One is reminded in this connection of the duckling that was inadvertently hatched by a hen along with a brood of chicks. Everything went well until one day in their wanderings the hen and her brood encountered a pond. The chicks behaved as properly reared chicks should, but the duckling was so delinquent as to take immediately to the water, thereby causing the disconcerted foster-mother no end of concern for the unbecoming conduct of her foster offspring. One suspects that the environment often gets the blame for a lot of things which can hardly be charged exclusively to its account. Who knows but that the pond, instead of being the cause of the duckling's downfall, was in reality the lucky chance that saved the poor duckling from heading directly for a nervous breakdown, which would ultimately have required the services of a duckling psychiatrist? At any rate, many will doubtless prefer to think that original nature had something to do with the fact that the same environment which led to the downfall of the duckling in the eyes of the foster hen, produced no such effect upon the chicks. Both Freud and Watson, in their cocksure pronouncements about the influence of early experiences, might well weigh the matter of individual differences in inherited constitution, as illustrated by the matter of the duckling and the pond.

Before the opening of the present century, Thorndike had achieved notable results in the study of learning expressed in objective terms in conformity with his well-known S – R formula, later used to good advantage by Pavlov. Thorndike always emphasized the fact that it was a highly complex *organism* which received the *stimulus* and that the nature of the organism always had much to do with the character of the *response*. The implied formula was S – O – R, with the "O" written large. But in the hands of Watson at a later date, the stimulus became the all-important factor. The organism was forgotten, and from his point of view it was the stimulus, that is the environment, which was responsible for the behavior which ensued. By 1917 Watson began to attract wide attention as a result of the experiments he had performed on the emotional learning of babies in a maternity hospital. He found that native responses were almost non-existent in the infant, and that it could easily be taught to exhibit the fear response to objects originally attractive in character. Watson interpreted these experiments as indicating that the infant is capable of rapid learning, that he can be shaped in any way desired by early training and that "There is no such thing as inheritance of capacity, talent, temperament, mental constitution and characteristics. These things depend on training that goes on mainly in the cradle."

Unfortunately, Watson soon ceased to be a university professor and became a professional advertiser, and his conclusions began to spread far beyond his data.

Also, unfortunately, his experiments on babies fell far short of meeting ordinary scientific standards.

Watson's general arguments in support of the potency of environment to the exclusion of the hereditary factor may be dismissed with very brief comment. As for the suggested view-point of the anthropologist to the effect that man's nature and inherent capacity were about the same "many millions of years ago" as they are to-day, and the implication that the differences between primitive man and civilized man are due to differences in the environment, one may well raise the question as to the nature and reliability of the evidence that man's nature and mental ability were the same many millions of years ago as to-day. If one skull is found of the millions of primitive men of a given age, what statistician will assure us that the one will be a reliable average of them all? And even if it were a reliable average, what psychologist will venture to give us a reliable measure of the intellectual capacity of such an individual on the basis of the measurements of his skull? Such arguments are hardly the kind of thing one would expect from an ultra-scientific experimental psychologist.

As for the sociological argument that a favorable environment may change a group or a nation to a cultural level far beyond that previously attained, the educator can agree most heartily. Surely the educator may be expected to believe in the potency of a favorable environment when that is what he makes it his professional business to supply. But this is beside the point. It does not touch the perplexing problem of individual differences at all. The improvement of the general average of a race as a whole does not bring about equal improvement for every member of the race or group. The moron is still with us in the finest educational system that any one has been able to devise. In fact, the intellectual differences between individuals become still wider as the educational opportunity is improved for all. The idiot remains an idiot, no matter what the environment in which he is reared, whereas the genius is able to capitalize fully upon his learning capacity only under conditions most favorable to the full exercise of his superb learning capacity. The damage is done by the implication that all infants are alike.

But the part of Watson's contention which requires most critical consideration is the experimental evidence which he claims to have secured in support of his conclusions. Following out the suggestion of Thorndike made in 1898 that "More fruitful than a host of questionnaires would be a set of experiments on children from birth on, in circumstances where their experience of, and instruction about things, could be regulated and its influence as a disturbing factor completely known," Watson nearly two decades later undertook to investigate the unlearned behavior of infants, and the aptitude of one or more of them to learn and unlearn fear responses. The infant exhibited the fear response well enough. Most any animal will do that. And wild animals have to be able to switch that response to different objects readily enough too if their chances of survival as individuals are to be worth much. Rats quickly learn to fear a trap that goes off with a zip and a bang. They don't need to be highly intellectual to do that. The shock will do the trick. It may be that the neural apparatus brought into action is lower down than the precious gray matter which the highbrow is supposed to employ. At any rate such learning is not necessarily an indication of future ability to learn calculus, provided behavioristic training is given in the cradle. In fact, one trouble with many humans is that they are too apt at learning fears, most of which are highly irrational. And all too frequently these block the way to the intellectual learning that the educational fraternity would like to see.

Watson was right enough in noting that here was learning that needed no mind, or at least a minimum of mind. If only he had realized that there might be different kinds of learning! For in some respects the learning of the chick or the rat seems to be different from the learning hopefully looked for in the classroom. One of the cardinal principles of scientific procedure, however, is to limit one's conclusions to the data under consideration. Immature minds tend to jump at conclusions. What a pity that Watson did not caution his readers that he was dealing with the most primitive form of emotional response and that this behavior might have little relaton to "capacity, talent, mental constitution and characteristics"!

Now as to Watson's conclusion that there is no such thing as inheritance of capacity because he finds little in the way of unlearned behavior at birth. Does it therefore follow that everything characteristic of adult behavior must be explained exclusively by learning? On this basis Spalding, working in 1875, would have been justified in denying that capacity for flight in birds is inherited. There was certainly no such capacity in evidence when the birds were hatched, and on the other hand ordinary observation gave every indication of gradual learning to fly on the part of the fledglings. But even at a date which is credited with being about four years in advance of the birthday of psychology as an experimental science, Spalding was too good a scientist to jump to such a conclusion without actual testing of other possible explanations. He eliminated the possibility of learning to fly by keeping a brood of swallows in cages too small for them to lift their wings, and then released them when the appropriate stage of maturation had been reached. They flew unaided, but there were marked individual differences in the effectiveness of their first attempts at flight. Some flew off with a sudden and amazing skill, one in particular flying right off out of sight, never to be seen again.

These experiments were repeated with different broods, and later repeated on three different species of birds. They proved conclusively that flight in birds must wait for the maturation of the motor and neural structures needed in flight, and that when that point is reached learning is unnecessary to explain a very creditable degree of performance. If this is what is meant by instinctive behavior, then birds such as these can fly instinctively. In other words, some capacity for such behavior is inherited. Moreover, when there is something there with which to practice as a result of maturation of inherited capacities, learning may proceed from that point.

In spite of much emphasis upon both maturation and individual differences in relation to learning on the part of later experimenters, Watson in his experiments with infants entirely ignored the possible influence of both. Many experiments, especially within the past few years, have demonstrated beyond doubt that a great deal of early behavior which superficial observation is prone to attribute to learning, turns out to have been almost or entirely uninfluenced by such "learning." Even in cases where the learning seems at first to be effective, the effect turns out to be superficial and temporary, with no permanent improvement in the capacity exercised at this premature period. For example, Gates, experimenting with carefully matched groups of five-year-old children, has shown that continued training in memory span over a period of five months resulted in marked improvement, but that the improvement had entirely disappeared four and a half months later. There was no evidence that the continued practice had increased any fundamental capacities. The control group which had had no training did just as well as the specially trained group. The same has been found to be true of motor functions, of linguistic development and of mental development in general by Gesell, Strayer, Hilgard, Goodenough and many others. The essential point seems to be that one can not develop an ability which is not yet there. To do so smacks too much of creation, and creation is for the almighty or the near-almighty. That is precisely the difficulty under which one labors in trying to educate an idiot. There is nothing there to work on. Maturation has had its chance, and nothing worth speaking of has materialized.

One can agree with Watson readily enough that there isn't much if anything there in the way of inherited capacity of an intellectual sort in early infancy. And again it is a pity that he did not have the patience to wait and test again at a later date. The development of the human organism has its beginning some nine months before the event of birth, and continues to mature for possibly as much as two decades after birth, depending upon the race and the individual. Why should birth be singled out as a time when hereditary factors might be assumed to cease to operate all of a sudden in shaping development, especially in view of the fact that birth takes place at variable ages and stages of development?

Now to come to the matter of Watson's discovery of the lack of individual differences in intelligence in early infancy. The fact itself is not to be denied. With nothing in the way of intellectual capacity yet discernible in any infant, one could hardly hope to find individual differences therein! But what is the approved technique for determining individual differences in intelligence? The only means relied upon by professionals is the use of a standardized scale for the measurement of intellectual capacity. But Watson, being an animal psychologist and not an educational psychologist, was possibly unaware of the need of such a tool for this purpose, or of the fact that there is no such test available for use in early infancy, for the good and sufficient reason that there is practically no mental behavior there to be tested at so immature an age. What behavior there is is almost entirely sensory-motor in character rather than intellectual.

To consider the positive side of the picture, what evidence can any one produce of intellectual training given in the cradle period that ever produced any permanent intellectual development? Much rhetoric has been expended in an attempt to prove the plasticity of infancy, but little if anything has been advanced in the way of evidence in support of this glamorous claim. If plasticity means modifiability or ability to learn, then early infancy would seem to be about the most unfavorable time of all, at least in the way of intellectual learning. Who is there among my readers, either of the gentler or of the more masterful sort, who will undertake to develop in the infant anything of intellectual significance during say the first three weeks after birth or even the first three months? To begin with, the infant is asleep a good deal of the time, though this should not greatly interfere with behavioristic learning which is independent of consciousness anyway. Certainly one can not teach the infant to talk at that age. How then is one to communicate any information? Surely this fantasy of prodigious learning which goes on mainly in the cradle must be relegated to the attic where most cradles are now to be located, if indeed they are not already in the discard. Experimental evidence all along the line has brought to light more and more the barriers to most kinds of learning at the earliest stages, and the gradually increasing capacity for learning up to age eighteen or beyond, rather than increasing capacity for learning as one approaches the date of birth.

VII

In view then of the assertions of Freud and of Watson from the outside of the educational circle that early experiences and training account for the differences in people, and of the persistent and rapidly accumulating evidence of the striking stability of inherited differences in intellectual capacity on the part of professional workers within the educational circle, is it any wonder that Terman in 1924 issued his educational broadcast calling for competent investigators everywhere to get down to business in an effort to solve the nature-nurture problem by a crusade of scientific exploration? The answer to the call materialized in February, 1928, as the two-volume Yearbook of the National Society for the Study of Education. The thirty-nine experimental studies and discussions finally accepted for publication in the Yearbook were restricted to just two considerations: "Nature and Nurture, Their Influence upon Intelligence," which constituted Volume I, and "Nature and Nurture, Their Influence upon Achievement," which constituted Volume II. No serious student of educational policy can afford to remain in ignorance of the essential contributions contained in these two volumes. Many of the experimental studies reported are highly technical and not to be mastered without careful study. However, the two most extensive studies, the California study sponsored by Terman and the Chicago study sponsored by Freeman, have to do with the effects of training given to adopted children. They remind me of a case which came under my observation some years ago. A philanthropist of considerable means, with whom I was well acquainted, adopted an infant son. The mother had died and the father was a good-natured, sociable but irresponsible ne'er-do-well with alcoholic tendencies. The philanthropist had a son of his own, a year or two older than the adopted son. Both boys in due time attended the same private school. But by the time the adopted son had reached the seventh grade, it became apparent that little was to be gained by keeping him at school any longer. By the time he was sixteen, he was detected taking small sums of money which did not belong to him, and using the money to treat his cronies to smokes and sweets. In temperament, intellectual capacity, sociability and even in manner of gait he was strikingly like his natural father, whom he had seldom seen. He later enlisted in the navy, while the natural son went on to college.

Here was an instance of two boys of very different heredity, both of whom from early days had been favored with essentially the same educational and social opportunities, and yet in spite of the similar if not identical environment, both developed largely in accordance with their own inherited natures, like the contrasting varieties of strawberry raised in the same field. Cultivation undoubtedly did something for both boys, but much more for the one than it was able to do for the other. Of course a single case such as this is in itself unconvincing. It may not be representative, and it lacks scientific rigor. It is merely suggestive and illustrative. The matter is put to the test of experiment in the California and the Chicago studies. Here the attempt is made to estimate or to measure the rise in the intelligence of adopted children when reared in superior homes, and the degree of resemblance of adopted children to their foster parents, as compared with the resemblance of true children to their own parents. The two studies agree quite well in part. They find that the rise in I.Q. as a result of being brought up in a superior foster home is limited to about six to nine points. As to the remaining data the studies diverge considerably in interpretation. The California study finds about 17 per cent. of the variation which takes place in intelligence under ordinary circumstances is due to the environmental factor, while 75 or 80 per cent. is due to the hereditary factor. The Chicago investigators, on the other hand, interpret their data as indicating that the environmental factor appears to be a decidedly potent one in determining intellectual development, or at least that it is by no means a factor of minor importance.

However, of all the studies reported in the Yearbook, the Chicago experiment stands out as the striking exception in this conclusion. The general conclusions may be summarized in part in the words of the editor of the yearbooks, who is also the permanent secretary of the society, as follows:

> Various human traits do not behave alike, and the relative influence of heredity and environment is something to be determined independently for each of the numerous traits that we strive to influence in the home and in the school.
>
> No one who reads the yearbook can put it away with the conviction that general intelligence is an absolutely fixed, immutable, innate capacity, but neither can one put it away with the conviction that general intelligence is readily susceptible to environmental influences.
>
> It is my impression that the data assembled emphasize the preponderant role of intelligence in conditioning school achievement. The Twenty-Seventh Yearbook strengthens the contentions of those who, speaking in hyperbole, are termed 'hereditarians.' The Yearbook so far as I can perceive, affords not a single straw to be clutched at by those extreme environmentalists who deny in toto the inheritance of intellectual disposition, and who would have us educational workers accept the staggering doctrine that, if we only knew our business, we could make of any child whatever we wished, even to fashioning of the proverbial silk purse from the sow's ear.

More recent investigations, notably those of Leahy at the University of Minnesota and that of Lawrence in England strongly support the conclusions of the California study. In short, recent data indicate in quite convincing fashion that the ***inherent intellectual capacity*** of an individual can not be very greatly increased by any known means of mental training at any period of mental development, and that under present educational conditions, the differences in ability and in achievement between school children are due to a far greater extent to differences in inherited nature than to differences in environment or in educational opportunity and training.

There are some indications that differences in personality traits may also be due to a considerably greater extent to inherited nature than to common differences in training, though the data on this point do not warrant any definite conclusion. Yet there is probably enough to make it advisable to suggest to the criminologist who is sure that an unfavorable environment is the whole cause of the career of the criminal that it would be advisable for him to recall the episode of the duckling which took to the pond, and to investigate the possibility of the inherited factor existing as a potential cause of at least certain types of crime, before being too sure that superficial indications tell the whole story. Certain it is that present theories of crime and methods of treatment based thereon can hardly be enthusiastically supported on the basis of their success in securing desired results.

VIII

One wonders how long it will be before those who behold the wonders that have been performed in plant cultivation and in animal breeding by more or less wholesale application of the principles of eugenics, will continue to stand aghast at the very thought of considering their possible application in human affairs in even the slightest degree. One wonders how long public lecturers, who readily admit the vast improvement which has taken place in stock raising by elimination of the most unfit by selective breeding, will continue to argue that it would be out of the question to improve the human race by the application of eugenic principles anyway, because one does not know which are the best human beings and which are the poorest! One might at least venture to hazard a guess that there are a few specimens whose pattern might be dispensed with without too much danger of loss on the part of future generations; and on the other hand that there are many whose progeny would be a very good bet to stand well above the average in many desirable traits. However, there is a ray of hope in the fact that public attitudes on other considerations have sometimes changed almost over night, as for example on the matter of woman suffrage.

In the last fifty years, a large part of the possible improvement of intellect by improvement of public educational facilities has already been accomplished. We are like the farmer who has drained the low spots on his farm, and fertilized the barren places, and cultivated the whole farm to the best of his ability, but still continues to plant any old seed with never a thought as to whether he might now turn his attention to improvement of his product by the simple expedient of more judicious selection of the seed to be planted, to the point at least of declining to plant seeds most likely to prove harmful, or of favoring the selection of seed most likely to give rise to the more desirable products—assuming of course that the human product is worthy of at least as much consideration as strawberries or cattle.

It goes against the grain to believe that men are not born equal, but it is true beyond doubt. Neither is it indicative of abnormality for an individual to have potential ability much above the average or much below the average. It is not abnormal to get a hand of bridge with a ten spot high occasionally, nor one with at least three aces. Just such combinations may happen in the distributions of chromosomes, even when the chromosomes from which the selection is made are the same, as is true in the case of children of the same parents. Such combinations are the result of natural forces just as much as are the combinations which occur more frequently, but it does not follow that the most unfortunate combinations need to be perpetuated eternally just because they occur, nor that the world's greatest assets deserve no thought toward their perpetuation.

It goes against the grain to have the outsider, the back-seat driver, tell one exactly how matters stand and what ought to be done about it. It takes persistent and usually thankless effort to get people away from accepting what has little or nothing to support it but wishful thinking. It is difficult to acquaint the general public with the facts laboriously brought to light by painstaking scientific research. How effective by way of comparison are the methods of the popular advertiser! And yet in the long run it is well worth the effort, for what but the truth may be relied upon to guide human effort so that the labor of millions may not be spent for that which is vain.

THE PHYSICIST'S NEW DELUSION

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It is a characteristic of human experience that one extreme generates another extreme, a good instance of which is to be found in current physics. The physicist at one time harbored the delusion of possessing absolute knowledge, and when that delusion was destroyed for him he sought refuge in the opposite delusion that he knew nothing, but sought refuge from that unpleasant delusion in another delusion, that because he knew nothing in physics he must know everything or a good deal in extra-physical matters like philosophy and particularly religion This is not implying that all physicists have gone off on that tangent, but it is a significant symptom of general conditions that those whose writings about current physics have attained the widest popular appeal have let loose a stream of speculations in the name of physics which is greeted with enthusiastic approval by a band which at one time shouted itself hoarse in denunciation of science but which hails it now as its strongest ally and friend. What has happened? Has physics lost its scientific status or has its historical enemy given up its dogmatisms? The answer is obvious, namely, that the dogmatic theologian has not come over to science, since he proclaims that science now supports his historical position, and therefore it must be that some scientists are giving him good cause for reaffirming his dogmatisms. Now when we recall what the scientist has suffered at the hands of the ecclesiastical dogmatist it is a betrayal of science and the scientists of the ages to give him any comfort and an opportunity to point his finger in derision and say "I told you so." The obscurantist and obstructionist is ever with us, whether openly or in disguise, and if he is given an inch he'll claim a mile. We should be jealous of science when we consider its uphill fight in the course of the centuries and when we bear in mind that every positive material good that mankind enjoys to-day has come from the scientific laboratory, whereas all evil that is still with us is due to traditional dogmatism obstructing the introduction of the scientific mentality into social affairs. Any comfort given to the enemy of science, though he may parade as its friend, is a betrayal of man simply because it is a betrayal of knowledge, and there is no knowledge that can benefit man other than the knowledge we call rational science.

But does not the physicist have the right to speculate? The answer is that when he speaks in the name of physics he has no right to speculate beyond physics, and when he does speculate beyond physics he should make it clear that he is not speaking as a physicist, and he should also make certain that he has the discipline for speculation in that extra-physical sphere. Now, speculators in the realm of physics like Eddington, Jeans, Millikan and Arthur Compton are guilty of two charges. They speculate in extra-physical spheres in the name of physics, and the quality of their speculations indicates their lack of discipline in those spheres. In other words, they go beyond physics in their physical speculations and they are naive in the method of their speculations.

Let us take an instance from Eddington. In one of his books Eddington is engaged in demonstrating the mystery of the universe as revealed by current physics, which leads him to proclaim the reality of religion also in the name of physics. One of his arguments runs as follows:

> If, for example, we admit that every thought in the mind is represented in the brain by a characteristic configuration of atoms, then if natural law determines the way in which the configuration of atoms succeed one another it will simultaneously determine the way in which thoughts succeed one another in the brain. Now the thought '7 times 9' in a boy's mind is not seldom succeeded by the thought of '65.' What has gone wrong? In the intervening moments of cogitation everything has proceeded by natural laws which are unbreakable. Nevertheless we insist that something has gone wrong. However closely we may associate thought with the physical machinery of the brain, the connection is dropped as irrelevant as soon as we consider the fundamental property of thought—that it may be correct or incorrect. The machinery cannot be anything but correct. We say that the brain which produces '7 times 9 are 63' is better than the brain which produces '7 times 9 are 65'; but it is not as a servant of natural law that it is better. Our approval of the first brain has no connection with natural law; it is determined by the type of thought which it produces, and that involves recognizing a domain of other type of law—law which ought to be kept, but may be broken Dismiss the idea that natural law can swallow up religion; it cannot even tackle the multiplication table.

Now here we have obscurantism of the most opaque type parading as physics, and playing right into the hands of the enemies of science That every statement here made is a misstatement, revealing the most deplorable ignorance of the nature of the learning process and neural activity, and that it is a mockery of God and religion to deduce both from a boy's ignorance of the multiplication table, is beside the point. The important point is that here is a man with a reputation as a scientist talking in extra-scientific realms in the name of science in a most deplorably unscientific manner. What is wrong? The answer is that in his philosophical and religious speculations Eddington and the rest are neither scientists nor philosophers nor religious thinkers. They are purely theologians, and poor ones at that. The demonstration of this thesis calls for a definition of science, philosophy and religion.

Science is a method of procedure, a way of thinking, that, judged by its results, offers the greatest promise to produce knowledge that enables us to deal most effectively or intelligently with our world. The factors that make this procedure intelligent are at least four in number. First and foremost scientific thinking draws a clear-cut distinction between what *can* be believed because of the reliable evidences or data on which it is based, and what *is* believed on the grounds of feeling, temperament, tradition or prejudice. This is a factor of intelligence simply because to mistake what is believed for what can be believed means harboring a delusion When any person feels that what he likes to believe is also what he can believe he is taking the first steps to a lunatic asylum. There are cases of course when that which is believed turns out to be also that which can be believed, but in all such cases that which is believed has been tested out by that which can be believed and found to be valid.

The second principle of scientific thought follows from the first, namely, that the evidences for that which can be believed must be beyond question, which means that they must be impersonal, public or universal data, or, in other words, that they are objective, measurable and causal. These three indispensable conditions of scientific data are intelligent simply because they are also the conditions of life or survival. We follow them in every activity that entails vital welfare. We could not go on living unless we followed the three postulates of objectivity, measurability and causality of our environment. A man crossing the street in traffic would not last long if he ignored the objectivity of the machines and the street, the measurability of the distance of the machine closest to him and the sequence of events or the relationship of the machines to himself.

Science is simply a refinement of these three conditions of life, in that its observations are more keen and detailed, its measurements more minute and its laws of causality therefore more dependable. It is because science follows these common-sense postulates of life that it has been able to contribute most to the promotion of life.

The third principle is one of caution prompted by the second principle, namely, that since scientific knowledge is based upon reliable evidences the scientist, as scientist, must keep within his evidences in all his conclusions and, furthermore, that no matter how reliable his evidences his conclusions are nevertheless only tentative, since further evidences might call for modifications. Consequently, when a scientist makes unqualified statements he ceases being a scientist and becomes a dogmatist. This is unintelligent because dogmatism obstructs progressive knowledge. Therefore, this third principle of skepticism even in the face of reliable evidences is intelligent because it is a safeguard against the delusion of the absolute. It is not the evidences that are in doubt, but the conclusions, because they may be based upon insufficient data.

The fourth principle follows from the others, namely, that since science is reliable knowledge it does not call for defenses, arguments, justification, denials or affirmations. It stands on its own feet. The scientist does not argue, plead, exhort, split logical hairs; he investigates and reports his findings as far as he has gone and for whatever they may be worth. When he begins to affirm, deny, defend or justify he is no longer a scientist, which means he is no longer intelligent, for there is no intelligence where there is no examination and investigation.

This, then, is science. It is knowledge that is reliable, dependable, because it is knowledge that is derived from reliable sources, knowledge that we can believe, knowledge that does not call for indoctrination or justification and knowledge that is constantly growing in accuracy and dependability. It is knowledge that grows out of life and therefore contributes to life.

If this account of science is accurate, then we must conclude that the philosophical and religious deductions from physics are unscientific, and the men who make them are not scientists, since in their inferences they violate every one of the principles of science. They draw deductions beyond and outside the intention of the evidences, they use that which they can believe to justify and defend that which they like to believe, and they argue and dogmatize.

Let us now turn to philosophy. What is philosophy and who is the philosopher? In a measure all human beings have a philosophy and all are philosophers. Only some are foolish while others are wise, depending on where their philosophy comes from. Philosophy arises from the insufficiency of science alone to satisfy life. The statement that man lives not by bread alone is a digest of the story of philosophy. The bread of life is science, knowledge. It sustains life, nourishes it and keeps it well. Life could not remain life without knowledge, and the more knowledge there is the safer and more abundant life becomes. But life to a human being is more than the sustaining of life. It includes also the meaning of life. There are, for human life, the actualities that must be observed if life is to continue and increase in safety, but there are also the ideals that call for realization if the life is to be a truly human life. For human beings, life as *is* assumes human significance only in the light of life as it can be. What can life be as seen from what it is, what are its potentialities, what is the life that human beings can live, that is worthy of them to live as human beings—all these are questions that human life raises and call for an answer. These questions go beyond the bread of life, and science has no answer for them and does not pretend to deal with them. But any answer to these questions must be based upon science if it is to have any validity, since it is only science that supplies valid data about the world and life. Now this is philosophy. Where science seeks truth about the world and life or facts and guards us against fancies, philosophy seeks truths for life or values to guard us against delusions. Philosophy is interested in the truths of science for the promotion of the truths of life. So where science analyzes philosophy synthesizes. Life must be seen not only as parts, but also as wholes, for the part is meaningless without the whole of which it is a part. The outlook of philosophy is therefore universal, while that of science is particular. Science sees the whole from the parts, philosophy views the parts from the whole. And both are indispensable, since a false view of the parts will lead to a delusion of the whole, and *vice versa.* This is the relationship of science to philosophy. The philosopher must have science if his philosophy is to be sound, and science calls for philosophy if its fruits are to be used in the interest of life. Progress in philosophy is dependent upon progress in science, but the progressive use of science in the service of life is dependent upon philosophy. But, and this is the crucial point, the philosopher, though he builds upon science and strives to be scientific in his thinking, does not claim scientific status for his philosophy. It is *his* philosophy, *his* cosmic, universal home, built out of the raw materials of science, and valid only for those who find his home comfortable. There is something compulsory in science—a man had better follow it; but there is nothing compulsory in a philosophy—a man might follow it. If a philosopher proclaims his philosophy as the only valid outlook he is no longer a philosopher, but a dogmatist. As a philosopher he distinguishes between what he likes to believe, namely, that his philosophy is universal, and what he can believe, namely, that it is his philosophy, having universal validity for him alone. In this respect he is in keeping with the spirit of science, although he is not a scientist.

From this analysis of the nature of philosophy we must therefore draw the further conclusion that the scientists here under discussion are no more philosophers in their philosophizings than they are scientists in the inferences they draw from physics. They do not build a philosophy out of science, but use physics to bolster up a preconceived philosophy for which they claim universal validity on the grounds that it is scientific. They are as anti-philosophical as they are anti-scientific.

Now as to religion. There are two views of religion: religion as belief in God, and religion as experience of God. The first is organized, established or public religion; the second is personal or private religion. The difference between the two is of vital importance because of their social consequences. The religious belief in God posits an objective deity whose existence is to be demonstrated by various proofs and belief in whom is to be indoctrinated or inculcated in various ways. This deity calls upon some persons to be his intermediaries and interpreters to man, and thus gives rise to a priestly class whose divine duty it becomes to instruct mankind in the will of this deity and whose divine privilege it is to intercede for man to this deity. This view of religion inevitably gives rise to a variety of religions, each holding a certain view of the nature of the deity, his will, his relation to man, and each proclaiming itself directly or indirectly as being the one and only true religion. The social consequence is division among men, enmities, suspicions, propaganda, indoctrinations and intolerance.

Religion as experience of God is the religion of creative experience, with God the creative spark in man urging him on to grow in creativeness, in manhood. In this religion there is no room for sin other than ignorance of one's real self and no room for virtue other than knowledge of this self. So God becomes the highest self of mankind in whom man is to find his real welfare Salvation for man is no easy attainment by accepting certain beliefs and engaging in certain mysterious practices, but is to be a constant seeking within oneself for that spark of divinity, which, as it is being found transforms its finder into itself. For this religion God has no being apart from man, and man has no being apart from God. As man is growing in manhood he is growing in Godhood, and thereby discovering God.

Now, the only relation between science and these two views of religion is this: that a scientific approach to religion shows that from the standpoint of human nature the religion of belief in God is a distortion of religion because it is a distortion of man, spreading confusion and enmity among men, while the religion of experience of God is true to human nature, for if it were in operation it would spread peace on earth and good-will among men. And it is this distorted, unscientific view of religion that current physics is alleged to support. Obviously an unscientific idea of religion can be supported only by an unscientific or distorted view of science, so that our theological-minded scientists violate science in support of a theological conception of religion. An objective God is not a religious experience but a theological dogma, and when science begins to support dogma it ceases being science, for science and dogma can not keep house together. Those scientists, then, who argue from physics to God and religion, use physics in support of an unscientific God, do so in an unscientific manner, and therefore only succeed in being anti-religion, although claiming to defend it and support it.

The conclusion is then that these men, speaking as scientists for philosophy and religion, are neither scientists nor philosophers nor religious thinkers. They are only theologians with a vengeance, for the theologian does not claim to speak as a scientist, but uses science as a prop whenever he can do so conveniently, while our scientists talk theology, and poor theology at that, as scientists in the name of science, to produce the impression that their theology is science. The result is that whereas the theologian of old was an open menace to science by trying to dictate to the scientist what he should or should not find in his investigations, the theological-minded scientist of to-day is a lurking menace in that he poses as a scientist in his theology and gives the theologian alleged scientific grounds for returning to his old practice of meddling in science.

ZERO AND THE CALENDAR

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OUR western (new style) calendar has been in use in parts of Europe since the time of its promulgation by Pope Gregory (1582) and in England since 1752. In America there is scarcely a household that is not supplied with at least a dozen every year. Yet ignorance of the calendar is at once profound and universal. The following generalizations seem warranted by the writer's experience:

A majority of the college population (including members of the faculty) are aware that leap year comes at intervals of four years.[1] But a greatly reduced number can state the rule governing the exceptions which excludes such years as 1900. A still smaller number know how the date for Easter is fixed. Fewer yet perhaps will answer with certainty when asked whether the death of Washington (1799) occurred in the last year of the century. And those who can compute the age of the emperor Augustus (63 B.C.–14 A.D.) are as scarce as those who understand Einstein.

The year just closed revived the question of the proper method of reckoning the time between two events, one B.C. and one A.D. For the classical teachers and scholars from Ireland to Australia selected 1935 as the year in which to celebrate the bimillennium of the poet Horace, born 65 B.C. Likewise the celebration of the bimillennium of Vergil, born 70 B.C., was initiated by the Italian Government with elaborate ceremonies and the issue of memorial stamps in 1930. And it is reported that plans are under way in Rome for the observance of the bimillennium of Augustus in 1937.

What is wrong with these dates? The trouble is that a bimillennium represents a lapse of 2,000 years, whereas the time between each pair of dates in question is 1999. The error arises in computing time as if 65 B.C., for example, were –65 years and 1935 A.D. were +1935. Numerous familiar scales of measurement are indeed constructed on this principle. Thus north and south latitude may be regarded as + and –, respectively. So also may west and east longitude, as well as temperature above and below zero. In each of these systems, however, as in the algebraic number scale, there is a number zero which divides the positive numbers from the negative, itself belonging to neither class. Thus the latitude of all points on the equator is zero, as is the longitude of all points on the prime meridian. *But there is no year zero in the (historian's) calendar.* Or, as Kubitschek[2] says, "The years 1 B.C. and 1 A.D. of ordinary usage follow one another directly without the intervention of zero." (See Diagram.)[3] Hence it is clear that a child born on December 8, 1 B.C. would be one year old (and not two) on December 8, 1 A.D. By the same token if Horace was born on December 8, 65 B.C., he would have been 65 years old on December 8, 1 A.D. (had he lived) and his bimillennium would occur 1935 years later, *i.e.*, on December 8, 1936.[3a]

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[1] The Roman priests were not even clear on this point. Thus during the first 36 years after the reform of the calendar by Julius Caesar, the priests decreed a leap year every three years. The resulting error of three days was corrected by Augustus, who omitted leap years altogether for a period of 12 years, restoring the Julian calendar.

[2] *Grundriss der Antiken Zeitrechnung,* München (1928), p. 13. See also Encyclopaedia Britannica, 11th ed., article "Chronology"; Giry, Manuel de Diplomatique, Paris, (1894), p. 89, footnote 2: "After the mode of reckoning in use, the year 753 of Rome is the year 1 B.C., the year 754, the year 1 A.D. Between the two periods ascending and descending, the computers have omitted zero"; Smith, *American Mathematical Monthly,* 38 (1930), p. 371; Herschel, "Outlines of Astronomy," 11th ed., p. 673.

[3] The Christian era thus dates from January 1, A.D. 1, while the birth of Christ is placed officially on December 25, of the year 1 B.C.! Authorities differ concerning the actual date of the birth of Christ.

3 B.C. | 2 B.C. | 1 B.C. | 1 A.D. | 2 A.D. | 3 A.D. |

Generally we have the rule for computing the time between events B.C. and A.D., as stated by Herschel (l.c.): "The sum of the nominal years B.C. and A.D. must be diminished by 1." This rule is emphasized by all the authorities on chronology from Ideler[4] (1825–6) to Kubitschek (1928), including the writer of the article "Chronology" in the Encyclopaedia Britannica, 11th edition, though I fail to find any mention of it in the latest edition of the Britannica either under chronology or calendar. Indeed two scholars, one of them a historian, writing for this work, have erred on this very point. In the article on Augustus occurs the statement: "He died on Aug. 19, A.D. 14 . . . on the anniversary of his entrance upon his first consulship 57 years before (43 B.C.)." Again in the article on Ovid, it is stated that the poet was born on March 20, 43 B.C. and that "He died in his sixty first year in A.D. 17." Both of these writers have plainly neglected to diminish by 1 the sum of the nominal years B.C. and A.D.

If those who wish to honor the bimillennial birthdays of ancient poets choose to ignore this rule and count inclusively, as the Romans did, that is their own affair.[5] Even they perhaps might demur at a hotel bill computed on this principle —for to the Romans "three days ago" meant day before yesterday. This inclusive counting, by which "every fourth year" was interpreted to mean once in three years, almost wrecked Caesar's calendar reform.[6]

It should also be observed that the number denoting the year in the calendar must be interpreted in the ordinal sense. The present year, *e.g.*, is the 1936th of the Christian era, but 1936 years will not have elapsed until the end of December 31.[7] The beginning of the twentieth century, therefore, about which there was much confusion and great argument, began with the beginning of the year 1901.[8]

Since there is no available event to mark the beginning of historical time, it was a stroke of genius on the part of Dionysius Exiguus (Denys the Small) to propose that the years be numbered in both directions from some intermediate event, such as the birth of Christ.[9] Most of the confusion mentioned above would have been avoided had he inserted a year zero in its proper sequence in the calendar scale. But historically there is the best of reasons for its omission: The number zero was probably unknown in Europe at the time the Dionysian system was adopted, in the sixth century. Zero seems to have been originated by the Hindus and used as a part of their positional system of notation. In this connection its function is to fill the empty places in such numbers as 4004 and it may have been a mere symbol of vacuity. Just when the concept of zero as a genuine number emerged is not clear, though rules for its combination with itself and other numbers in arithmetical operations are given by Brahmagupta (*c.* 628). [10] Recent research seems to confirm the view that a place-value zero was known in India as early as 500 A.D., or possibly earlier.[11] But the earliest occurrence in India of the symbol 0, according to D. E. Smith,[12] is in an inscription of 876; while the oldest European manuscript which contains the Hindu numerals (without the zero, however) was written in Spain in 976.

[3a] *Cf.* Pogo, *Popular Astronomy*, March, 1936.

[4] "Handbuch der Mathematischen und Technischen Chronologie," two volumes.

[5] Fotheringham, writing for the *Classical Review* (Vol. 34, 1930), recognizes the absence of a year zero and argues for 1931 as the proper year in which to celebrate the Vergil bimillennium.

[6] Footnote 1.

[7] This is well understood with respect to the days of the month. March 10 is the name of a day, the tenth of the month, but 10 days of March will not have passed until the midnight between March 10 and March 11.

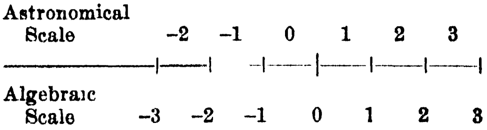
[8] Even Eells, correcting his error in counting anniversaries (*School and Society*, December, 1930), says: "This is due to the fact that the first year of the Christian era was numbered one not zero while the first year of every century since begins with '00'." But surely 1 + 100 = 101, hence the second and every century thereafter begins with —01.

[9] He took for the beginning of the Christian era, March 25, 1 B.C., *i.e.*, the date of the Annunciation.

Long ago Ideler (*loc. cit.*) remarked on another difficulty of the historian's calendar, namely, that leap years are now numbered, 4, 8, 12, etc., A.D. but 1, 5, 9, etc. in the era B.C. And he observed that if 1 B.C. were changed to 0, 2 B.C. to –1, etc. not only would leap years be named by multiples of 4 in all cases, but the time between two events before and after the beginning of the Christian era would then be found correctly by adding the number of positive and negative years. This method of reckoning time, now generally adopted by astronomers, was introduced by Jacob Cassini, according to Kubitschek, and first used in the introduction to his "Tables Astronomiques," 1740, page 5. Schram,[13] commenting on this system, says:

> Zero is often falsely understood and identified with "nothing," whereas it is nothing but the number coming before unity in the natural number scale. No one will deny that 18, 19, 20, 21, 22 are five consecutive numbers which might denote any five consecutive years; then an interval ten years earlier would be denoted by 8, 9, 10, 11, 12, and an interval ten years still earlier by –2, –1, 0, 1, 2. This however the historians will not recognize but call these years 3 B.C., 2 B.C., 1 B.C., 1 A.D., 2 A.D., so that zero has been thrust out of its natural number sequence. Thus we have two systems of numbering years before the birth of Christ, the astronomical and the historical which differ from one another by one unit.[14]

In the astronomer's calendar, the birth of Augustus would be placed in the year –62, consequently his bimillennium, computed as in elementary algebra, would fall in 1938. There is one important difference, however, between the astronomer's calendar and the algebraic scale: When plotting numbers in algebra, each number corresponds to a single point, 0 marking the point of origin. In the calendar, on the other hand, each integral number designates an entire year. (See accompanying diagram).



In the algebraic scale we have naturally made the number 0 correspond to the beginning of the Christian era. On the algebraic scale the number attached to any point, whether integral or not, indicates the exact time interval measured from the beginning of the Christian era. Thus April 1 of the year 3 (A.D.) corresponds on the algebraic scale approximately to 2.25, which is the time elapsed from the beginning of the Christian era. Again April 1 of the year –2 would be represented on the algebraic scale approximately by –2.75, which gives the number of years before the era.

The astronomer's calendar would more nearly conform to our experience in measuring if it had placed the beginning of the Christian era at the beginning of the year 0 instead of at the end. This could be accomplished by sliding the whole astronomical scale of the above diagram one unit to the right, making 0 the first year of the Christian era. The dates B.C. would then be the same as in the present historian's calendar, while each date A.D. would be increased by 1.[15] The number denoting the year A.D. would then indicate the integral number of years elapsed from the beginning of the era. Now April 1, A.D. 2 (or the year +2) would correspond on the algebraic scale to 2.25, and the time elapsed is 2 + .25 (the time from January 1 to April 1); and April 1, B C. 2 (*i.e.*, the year –2) would correspond on the algebraic scale to –1.75, which is –2 + .25 (the time from January 1 to April 1). Thus in each case the fractional year added is positive—due to the fact that time moves forward—while the integral year, *i.e.*, its ordinal number in the calendar, may be either positive or negative. This is entirely analogous to the notation used in writing logarithms, where commonly the mantissa (the decimal part) is taken as positive, whereas the characteristic (the integral part) may be either positive or negative.

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[10] Datta, *Bulletin, Calcutta Mathematical Society*, 18: 165–176, 1927.

[11] See a series of papers with references in the *American Mathematical Monthly*: (1) by Datta, 33: 220, 449, 1926, also 38: 566, 1931; (2) by Ganguli, 34: 409, 1927; 39: 251 and 389, 1932; 40: 25 and 154, 1933. Or, Datta and Singh, "History of Hindu Mathematics," Lahore. 1935.

[12] "History of Mathematics," Vol. II, p. 69 and 75.

[13] "Kalendariographische und Chronologische Tafeln" (Leipzig, 1908).

[14] Quoted from Kubitschek, *loc. cit.*, p. 18.

It is unfortunate that a zero year has not been introduced in the calendar of the historian and the chronologist. And since zero in the calendar stands for a whole year and not a single instant of time as it would in the algebraic scale, perhaps the astronomer's choice is the most satisfactory under all the circumstances. That would require only the change of the dates B.C., relatively few of which are known with certainty. The years of the Christian era would be numbered as at present, starting with 1, as we number the days of the month, automobile licenses, the pages of a book.[16] The chronologists could institute such a reform by simple agreement among themselves. If they are unwilling to insert a zero year in the calendar, then let the writers of school histories explain its absence and the embarrassment which its omission entails. In the matter of reckoning time, "It wad frae mony a blunder free us."

Many of the difficulties of a satsifactory calendar are inherent. Foremost of these perhaps is the fact that the three most natural units of time, namely, the periods of the rotation of the earth on its axis, the revolution of the moon about the earth and the earth about the sun are incommensurable. That is, neither the year nor the (lunar) month contains an integral number of days, nor is the fractional residue of a day a rational number such as ¼ or ⅛. Some of the anomalies of our present calendar are accidental or at least avoidable, such, for example, as the incidence of New Year on different days of the week and of Easter on different days of the year in two different months. The correction of these irregularities was the hope of a vigorous agitation for calendar reform a few years ago, which however has somewhat subsided of late.

There remain serious problems of chronology which have been bequeathed to us from the past. A major source of confusion has been the use of different calendars by different countries. Another is the use of different calendars by the same country at different periods of its history or even the same period. For example, the civil year and the ecclesiastical year have not always agreed, while the astronomical year agrees with neither. Indeed, there are several astronomical years all in good standing.

Not only has the length of the year varied, but the beginning of the year has been fixed at numerous dates.[17] Among the dates selected to mark the beginning of the year, four are related to the life of Christ: March 25 (style of the annunciation), December 25 (style of the nativity), January 1 (style of the circumcision) and Easter (style of France).

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[15] Leap years would then be numbered 3, 7, 11, etc., A.D., B.C. dates being unaffected.

[16] The whimsical author William DeMorgan, I believe, called the first chapter of one of his books Chapter 0; and I have seen a set of mathematical axioms numbered, 0, 1, 2, etc.

[17] See particularly Giry, Chapter II.

Others were doubtless determined by the seasons. Both the vernal and autumnal equinoxes have been used.[18] Also may be mentioned September 1 and 24 (Greek), March 1 (Roman religious and German) and August 11 (Danish). Likewise the beginning of the day has been reckoned variously from sunrise, noon, sunset and midnight. Again every instant of day and night on a fixed meridian is (solar) noon on some other. And in crossing the international date line one changes time by an entire day.

With all this multiplicity of calendars, whose months and years are of varying length, together with irregular and sometimes capricious intercalations of days and months, it requires no imagination to perceive that the problem of an accurate historical chronology is one of the greatest complexity To quote Herschel, page 674:

> The history of the calendar, with reference to Chronology, . . . may be compared to that of a clock, going regularly when left to itself, but sometimes forgotten to be wound up, and when wound, sometimes set forward, sometimes backward, either to serve particular purposes and private interests, or to rectify blunders in setting.

And he might have added that the clock records no zero time!

THE ANTIQUITY OF MAN IN AMERICA

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THAT man may have lived in North America for a good many thousand years has been a subject for discussion off and on since the middle of the eighteenth century; but these discussions attracted very little attention till discoveries in Europe demonstrated the existence of man at an early period on that continent. These disclosures tended to promote search in America for evidence of an equally early culture. The period immediately preceding and subsequent to the Civil War was marked by such announcements of the finding of traces of early man as those at Trenton, N. J., those from the auriferous gravels of California and others from Minnesota, Kansas, and so on.

EARLY APPEARANCE NOW CONCEDED

One by one these claims to antiquity were attacked by scientists who could not subscribe to the theory that man had existed in the New World for such a long time. In spite of this, however, reports of discoveries of extinct animal bones in association with human remains or objects of human manufacture continued to appear from time to time in North America, until finally the evidence from Folsom, New Mexico, made it apparent to every one that man was present in that region at an earlier period than many supposed. This discovery immediately galvanized general interest in the subject of man's antiquity and promoted activity along this line in various parts of the country.

In the light of these results and others subsequently obtained, I doubt if there is any one to-day who is not willing to concede that the evidence is ample for believing that man had been in North America for several thousand years before the beginning of the Christian era. This, it will be admitted, is not very satisfactory dating, but it will have to suffice till more is known about glacial geology, and more particularly with regard to those regions that were not glaciated during the Wisconsin stage.

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[18] Christmas and January 1 too come near the winter solstice and Easter near the vernal equinox. January 1 marked the beginning of the Roman year 150 years before the Christian era.

What is becoming increasingly clear is that the associations occurring at Folsom, at Clovis and at other sites, more recently investigated, point to climatic conditions that were different from those that exist at the present time in the same regions. The evidence is for a colder and a more moist climate at the time the deposits were laid down, and in some localities the types of shells and microscopic examination of samples from the deposits indicate a progression towards a milder climate, with more arid conditions. Many of the animal bones represent types that are altogether extinct to-day in the region in which they are found, or represent types that to-day live in entirely different environments.

EVIDENCE OBTAINED AT CLOVIS

To be a little more specific, we may now consider the results obtained at Clovis, New Mexico. Here there is such evidence as we have been discussing that man lived in the region at a moderately early time. Taking it up briefly, we may consider the subject from the three points of view of geology, paleontology, and archeology.

The physiography of the Clovis region presents an almost flat surface, which is characteristic of the Staked Plains of eastern New Mexico and northwestern Texas—a surface that is almost uneroded. There are, however, a series of basin-like depressions, with surrounding sand-dunes, that break the monotony of the landscape between Portales and Clovis. These basins are made up of bluish-gray silt and clay deposits, probably representing old lake beds, which once formed part of the Brazos River system, when that river extended much farther west.

These deposits have been exposed by the wind, and it is in and on the bluish-gray clays that the bones of the bison and the elephant are found, and in which worked flints and lenses of charcoal appear. A casual examination of this area will lead one to form the opinion that not much can be done in the way of determining the age of these deposits, but a more thorough study reveals the fact that the evidence fits well into the general picture as it is being developed in the Southwest.

DATING THE BEDS

In an attempt to date these beds at Clovis, Dr. Antevs spent some time summer before last investigating the evidence in New Mexico of geological features that might tie in with the bone-bearing strata at Clovis. Based upon a study of the data obtained, near Willard, New Mexico, almost due west of Clovis in the center of the state, where well-developed shore lines show that an ancient lake had existed, Dr. Antevs believes that the highest stand of the lake, at that earlier time being about 150 feet deep, and covering about 450 square miles, corresponded to a period somewhat earlier than that when modern temperature conditions were attained in the Southwest.

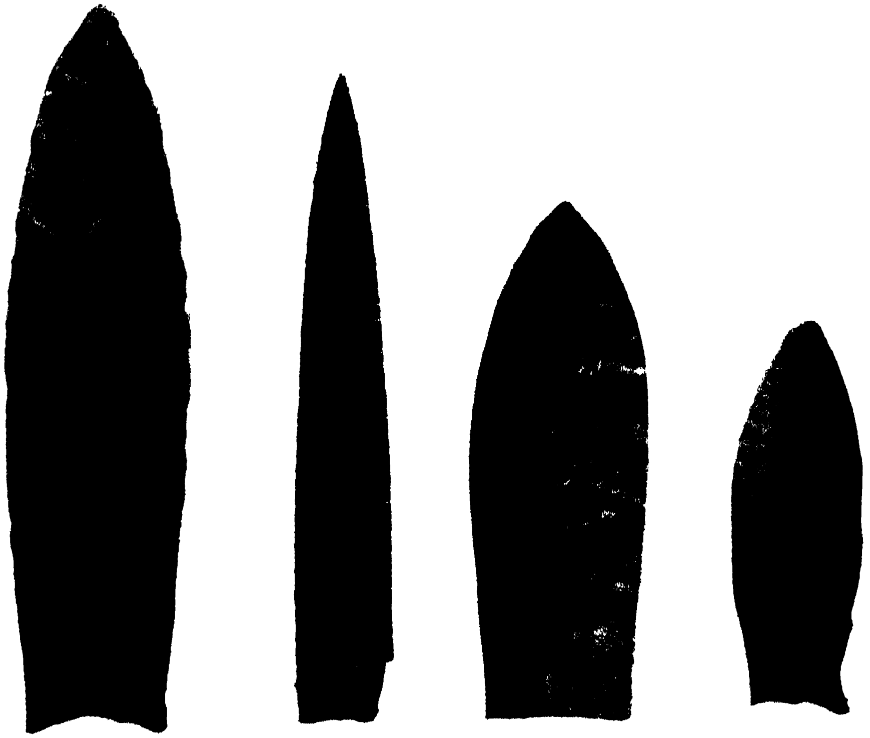
Dr. Antevs accordingly places the high stand of this ancient Lake Estancia at about 15,000 years ago, and he estimates the time when the clays were finally laid down at Clovis at 12,000 to 13,000 years ago. Apparently the estimate of 10,000 years, previously made for the age of the Clovis discoveries, seems to have been conservative.

CLOVIS AND FOLSOM FINDS COMPARED

Of the animal bones discovered at Clovis, those of the mammoth and bison are found in the bluish-gray deposits, the horse and camel in the top of the underlying beds. Dr. Stock is at present occupied with the identification of the specimens from this site, and his report

is looked forward to with interest. It was the exposure of bison and mammoth bones in nearly every one of these basins that first suggested the possibility of association with human objects, since quantities of flint tools and chips were scattered over the surface of these same basins.

Without the knowledge gained by a study of the Folsom site that at Clovis would have presented a very much more difficult task to interpret, bearing in mind that the Lindenmeier discoveries, near Fort Collins, Colorado, had not yet been announced by Dr. Roberts. Everything about this newest discovery of Folsom artifacts in Colorado tends to show that the same people had lived at Clovis at about the same time. Identical types of artifacts are found at each place, and the geological evidence in each place seems to point to a time when climatic conditions were different than at the present time, as already mentioned.



TYPES OF EARLY ARTIFACTS

THE FIRST IS A “FOLSOM-LIKE” POINT, SOMEWHAT CRUDER THAN THE SO-CALLED “FOLSOM” TYPE; THE SECOND IS A “YUMA” TYPE, SHOWING FINE, RIBBON LIKE FLAKING ON ITS FACE; THE THIRD IS A KNIFE; THE FOURTH REPRESENTS THE “FISH-TAIL” TYPE OF THE “FOLSOM-LIKE” POINT.

The Folsom Type of Spearpoint

Though end- and side-scrapers were found at Clovis, the Folsom point is the important type that furnished the clue to the site in the first place. This particular type of spearpoint can be briefly described as a thin leaf-shaped point, the chief characteristic being a longitudinal groove along each, or sometimes only one face. The base is concave, with ear-like projections. The secondary chipping is very fine and shows remarkable control of the flaking tool.

The general character of these points, as well as those of the equally well-

TOOTH OF EXTINCT ELEPHANT

FROM THE CLOVIS, NEW MEXICO, GRAVEL-PIT. THE NUMBER OF BONES OF EXTINCT BISON AND ELEPHANTS FOUND IN THIS PIT IS SO GREAT AS TO SUGGEST THAT IT ONCE MAY HAVE BEEN A WATERHOLE IN WHICH THESE ANIMALS BOGGED DOWN.

chipped points known as Yuma points, has led to comparison of these early American artifacts with those of the European Solutrean culture. There is no doubt that there is a striking likeness in some of the shapes of both, and that both types represent pressure flaking of a high order. Nevertheless, after examining a number of Solutrean blades and points last summer in France, one feels the necessity of reserving opinion upon the subject till a more detailed study is made of the whole situation. Off hand it seems unlikely that there can be any direct connection between the two cultures, but there is a possibility that both may trace their beginnings to Asia.

As a matter of fact the Danish neolithic points and daggers offer more exact comparison with the points of our Folsom-Yuma complex than anything else in Europe, except, of course, that none of the Danish points have the longitudinal groove, characteristic of the Folsom point. This particular grooved type, so far as I have been able to ascertain, has not been observed anywhere in Europe or Africa.

Last summer, in order to find out whether anything approaching the Fol-

THE JAWBONE OF EXTINCT BISON

FOUND IN A GRAVEL PIT NEAR CLOVIS, NEW MEXICO. CHARCOAL AND BURNED BONES, EVIDENCE OF EARLY MAN, WERE ALSO FOUND HERE.

som point had been found in Siberia, I went to Russia under a grant from the American Philosophical Society, and at Leningrad had an opportunity to study the collections in the museums from Siberia. There were no types like our Folsom points, but, as archeological material of this nature from Siberia was limited, it may not be wise to make any sweeping statements as yet about these highly specialized artifacts or their prototypes from that country.

Folsom-like Points

The facts as observed point to the flaked groove point as being a development of North American origin. Dr. Hrdlička reports the finding of rubbed groove points of slate from Alaska, but these are of a later period than the Folsom points. A technique similar to that of these Alaska points has been reported from Manchuria, said to be of the pre-Han period.

To come back now to the Folsom point, it should be noted that its distribution is somewhat confused by the fact that there are grooved points found in other parts of North America as well as the Southwest, which differ from the typical Folsom point as found at Folsom and other relatively near-by sites. Whether they are earlier, later or contemporaneous with the true Folsom type can not be determined at this time.

We found one of these more generalized types of Folsom point called Folsom-like points, in a cave in the Guadalupe Mountains of New Mexico, southwest of Clovis, at a level definitely below that of a Basket Maker people who had used the cave for burial purposes. These lower levels of the cave contained numerous lenses of charcoal and the bones of a number of animals that have been extinct in that region for a long time, such as those of the camel, horse, antelope, bison of extinct species and musk-ox.

Not, however, till more facts are gathered upon the subject of glacial geology and the question of post-glacial climatic fluctuations, and until more is known of the types of stone tools made by our prehistoric peoples, shall we be able to project upon the screen of research a clear picture of what America was like before the Christian era.

THE REAL WINNERS IN THE 1936 OLYMPIC GAMES

By Dr. CHARLES D. SNYDER
PROFESSOR OF EXPERIMENTAL PHYSIOLOGY, JOHNS HOPKINS UNIVERSITY

PERHAPS it has occurred to others besides myself that the absolute scores accredited to the various countries in the Olympiad just ended in Berlin somehow do not represent their respective relative positions of excellence

For one thing the number of people in each of the countries from which their representatives were chosen is a vastly various quantity. It is not unreasonable to assume that, given equal opportunity and training, the human animal ought to wrest his share of honors, in such a variety of sports as the Games included, regardless of the country he represents This being granted as an ideal state of affairs, it would follow then that the total score of points won by any one country may well be in direct proportion to its population. If in reality this turns out not to be the case, then may we begin to search for the causes of the differences

In order to make use of the population factor in revaluating the scores, I have made use of "the unofficial" final scores accredited to each nation in the Associated Press report as published on August 17, 1936. The dispatch listed 28 countries. Of these I omit the three countries which, in any way one treats the figures, obviously will stand at the bottom of the list, namely India, Roumania and Turkey. From standard references I have noted down the population figures for all the rest of the 25 countries listed, together with the "unofficial" score assigned to each. Adding up the two columns gives a grand total population of 560.83 millions in all the countries considered, whose total scores likewise sum up to 533 points. If one now divide the total number of points by the total population expressed as millions, one has a fraction of 0.986, which represents the distribution of points for each million of the total of all populations represented in the Games.

To get the ideal score for each country then, all one need do is to multiply the population of each country by the factor given above, namely, 0 986 This ideal score then may be compared with the score actually won, and the question as to how nearly each country by its earned score has realized its ideal score may be answered in terms of per cent. This is done by dividing the earned score by the ideal score and multiplying by 100

The results of such an inquiry, together with the pertinent data, appear in Table 1, where the first column of figures gives the population in millions; the second column, the respective "ideal score" cal-

TABLE 1
THE 1936 OLYMPIAD ALL EVENTS REVALUATED ON A POPULATION BASIS

Country	Population in millions	Ideal score, on population basis	Actual score earned	Percentage of ideal score realized
Esthonia .	1 17	1 15	6	522
Hungary . ..	8 67	8.53	43	517
Sweden	6 10	6.01	25 5	508
Finland .. .	3.63	3 57	17	476
Austria . . .	6 68	6 58	26	396
Norway .	2 65	2.61	9	345
Holland	7.83	7 72	24	311
Switzerland . .	3 88	3.82	10 5	275
Germany	64.60	63.60	134	195
Argentina .	10.92	10.77	16	149
Canada	9 66	9.52	9	94 5
Italy	41 49	40.80	55 5	87.0
France	40 92	40 30	31	86.9
U. S A. . . .	121.74	119.80	77 5	64.8
Belgium .. .	8 05	7.94	5	63 1
Czechoslovakia .	14.73	14.53	9	62.0
Denmark ..	3.48	3.43	2	58.4
Uruguay	1.81	1.78	1	56.3
Mexico	14.80	14.60	8	54 8
Egypt	14.18	13.97	7.5	53.8
Great Britain .	43.03	42 40	20 5	48.4
Poland	27.18	26.90	11 0	40.9
Yugoslavia	13.42	13.23	2	17 65
Philippines	11.57	11.4	2	17.5
Japan	76.69	75.5	11	14.6
Totals	560.83		553 0	

culated on the population basis, as indicated above; the third column, the earned score as accredited by the Associated Press dispatch. The last column contains the percentage of its ideal score that each country has realized by its earned score. It is this last figure which determines now the real position of excellence of each country in respect to all the others. Indeed, in the final construction of the table, and for the convenience of the reader, the order of naming the countries (and giving their appropriate data) was selected on this basis. It is needless to remark that order of excellence here turns out to be quite different from the order when based on the absolute number of points won.

Inspection of the table reveals some startling facts. Germany and U. S. A. no longer lead, but appear ninth and fourteenth, Japan drops down from twelfth place to the end of the column. It becomes quite obvious that, under present conditions at least, it is the snug little countries of northern Europe that can win from 2.5 to 5 times their alloted ideal scores, whereas the countries of larger populations, wherever they are, can only take middle positions, realizing at best only from ¾ to 2 times their allotments on a population basis. The U. S. A. with her 64.8 per cent. can only boast of leading those countries which have definitely failed to hold their own, including Great Britain, who has failed badly.

Many of us still consider the events of track and field as the noblest sports, and since they represent more nearly the games played in the original Olympiads it is of interest to revaluate the scores accredited to the various countries for these events alone, as we have done above for all events. This has been done using the unofficial scores again (for both men and women) as they were compiled in the Associated Press dispatch of August 9. The results appear in Table 2. And it is important to compare this table for track and field with that of all events.

TABLE 2

TRACK AND FIELD EVENTS REVALUATED ON A POPULATION BASIS*

Country	Population in millions	Ideal score	Actual points won	Percentage score realized
Finland ..	3 63	4 54	80 1/4	1776
New Zealand	1 54	1 9	10	579
Sweden	6 10	7 6	19 1/11	251
Canada	9 66	12 1	30 1/11	248
Switzerland	3 88	4 7	9	193
Holland	7 83	9 8	16 1/3	167
Norway	2 65	3 3	5	153
Germany .	64 60	80 1	121 1/4	150
U S A	121 74	152 2	225 1/3	148
Latvia	2 35	2 9	4	138
Hungary	8 67	10 8	11 2/11	103
Great Britain	43 03	53 9	53 1/11	100
Italy	41 49	51 9	36 13/22	71
Japan .	76 69	96 1	58 13/22	61
Australia	8 18	10 2	4 1/3	40
Austria .	6 68	8 5	3 2/11	38
Argentina	10 92	13 7	4	29
Philippines	11 57	14 5	4	28
Greece	6 20	7 9	2	25
Czechoslovakia	14 73	18 4	3 1/11	16 4/5
Poland	27 18	34 3	5 1/11	15
France	40 92	51 2	2 1/2	4 9/10
Brazil	39 69	49 7	2	4
South African Union	7 78	9 7	2/11	2

* Calculated from the Associated Press accredited scores of August 9

In the first place, taking the countries all in all, the main lines of demarcation remain the same in both tables. The little countries of northern Europe still head the list, with little Finland doing nearly 18 times more than her share of realizing on her population basis. Germany and the U. S. A. realize nearly one and one half their shares, and Great Britain registers more nearly as we think of her, that is, as a country who takes her sports leisurely and with pleasure rather than grimly and strenuously. She scores just 100 per cent. of the points allotted her on a population basis. While Denmark and Belgium do not score enough to appear at all in the list, there are Latvia and Hungary just ahead of Great Britain. The lower half of the table is made up of those countries which realized in track and field less than 100 per cent. of the scores allotted them on the population bases. It includes now Austria and Argentina, each of whom for all-events realized more than 100 per cent. On the whole, however, for track and field, as for all events, the larger countries seem to be able to do no better than to take middle positions, some of them again taking positions down at the bottom of the list.

One is tempted sorely to speculate as to the reasons for this great diversity in athletic prowess. When Owens was winning his wonderful races a great cry went up in the American press proclaiming that once and for all the myth of superiority of one race over another had been smashed. Perhaps in the short race (as has been suggested) some anatomical advantage of bone or muscle structure gives the black man advantage over the white. In any case we must remember that the Negro boys were trained by white men in the white man's institutions. Until some actual research is carried out we are obliged to regard slight anatomical variations among peoples not so much the determining factors for winners as are the more subtle qualities of character and spirit added to the well-trained body. Luckily the games run off at the Olympiad were varied enough to give all peoples some chance to show what they may do well and thus gain points.

It is generally stated by anthropologists that all the nations of the world are made up of mixed races. Some of them, however, are much more mixed than others. It surely is an arresting fact that the countries standing in the upper half of the table represent the homelands of what remnants there are of the once "great northern races," and that, with the exception of Denmark, those countries appearing in the lower half of the list are on the whole those whose populations represent the greatest racial mixtures.[1]

Looking again for a moment at the table for track and field one notes that it is just the little countries in the leading places that have no international debts, save Finland; and she, of all the European countries that have such debts, is the only one who has been meeting her obligations as they come due, a feat compared to which in these decadent days the winning of athletic games seems indeed to be mere child's play.

Political unrest and economic instability therefore may be playing a rôle, but just what is not clear. Since the late war Esthonia, Hungary and Austria surely have had their share of troubles, yet they score high in the all-events table; whereas comparative calm and security apparently have not helped Denmark and the Philippines to lift themselves out of the class of mediocrity.

By far the clearest point revealed by the tables is the fact that mere bigness does not guarantee superiority in athletic sports for any land. Rather it would seem that the results of the Games bear out what is known to be a truth, namely, that with spread of empire the quality of the average individual weakens, which in turn is probably largely due to increased racial interbreeding.

The world being what it is, it would be perhaps too much to hope that with the renewal of the Olympiads the nations of the world would so order their affairs that at some not too distant date the scores their youths bring home will approach more and more nearly 100 per cent. of their shares allotted on the population basis.

To hasten this day the committee in charge of the Games has done much, and may do more. First, by fostering to the utmost the friendly, generous spirit of sportsmanship; second, by adding to the number of events, to be held in the matches as many as possible of the games each country finds itself able to play well. Surely nothing the nations have undertaken together thus far has done so much for international understanding and appreciation as have the Olympic Games of the present century.

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[1] The reader doubtless recalls arguments in favor of racial interbreeding. But athletic scores put on a population basis, as above, give no support whatever to such arguments, which after all are in the nature of wish fulfilments. The main thesis also of such articles as the recent one by Powers and Webster on "The Coloured Shadow in Sport" (*Liberty*, New York, and condensed in *Magazine Digest* for August, 1936) are thereby shown to be equally groundless.

THE PROGRESS OF SCIENCE

THE HARVARD TERCENTENARY MEETING OF THE AMERICAN ASTRONOMICAL SOCIETY

THE fall meeting of the American Astronomical Society was held at Harvard University during the first week of the Tercentenary Conference in September; sixty-six papers were presented at the morning sessions. The initial paper gave one of the outstanding contributions of the meeting. Professor E. W. Brown, of Yale University, reported on investigations dealing with the stellar case of the problem of three bodies. He studied the perturbations from the purely elliptical motion that will arise when the orbits in a close binary system are affected by the action of a distant third body. The problem reminds one of the lunar problem, but the essential difference lies in the fact that the mass of the sun is roughly 300,000 times the combined mass of the earth-moon system, whereas the three stars involved in the stellar case may be assumed to have comparable masses. Brown has found that the stellar case can be solved to a high degree of approximation if he includes only a comparatively small number of terms in his series for the perturbations of the elements and that his solutions will hold for practically any value of the eccentricity or inclination.

Drs. P. van de Kamp, A. N. Vyssotsky and Emma Williams-Vyssotsky, from the McCormick Observatory of the University of Virginia, reported on the analysis of their large material of proper motions for faint stars. Important information on the decrease of star density perpendicular to the galactic plane has been obtained and the rapid falling off found for the red dwarf stars was one of their most startling results. The discovery of faint stars of low temperature was the subject of two papers, one by Dr. C. W. Hetzler, of the Yerkes Observatory, and a second one by Dr. V. M. Slipher and Miss Alice M. Rogers, of the Lowell Observatory. Both papers gave lists of very red stars that have already been found, and Hetzler suggested a surface temperature of hardly more than 1,000° C. for some of the objects in his survey.

Nova Herculis was given a good deal of attention and reports on the changes in its spectrum were made by representatives from the Perkins Observatory, the Observatory of the University of Michigan and the Dominion Astrophysical Observatory. Velocities as high as 3,500 km/sec had been recorded for some of the expanding shells shortly before the disappearance of the continuous spectrum of the nova. Of particular interest was an attempt to determine the distance of the nova from the intensities of the interstellar lines by Dr. J. A. Pearce, which yielded an approximate value for this distance of 2,000 light years.

Drs. P. W. Merrill and O. C. Wilson, of the Mount Wilson Observatory, have made further studies of the intensities of interstellar lines. They find that the interstellar lines of unknown origin, towards the red end of the spectrum, are extremely strong and that their intensities exceed considerably those of the well-known interstellar D lines, owing to sodium, and the H and K lines, owing to ionized calcium. Dr. Orren Mohler, of the Cook Observatory of Wynnewood, Pa., reported on studies of solar radiation in the wave-length interval 2,000 to 2,300 Ångströms. He showed that some of the solar radiation in the ultra-violet will undoubtedly penetrate through our atmosphere in sufficient amount to be detectable at an altitude of only forty meters above sea-level. His observations did not indicate that the intensity of the radiation between 2,000 and 2,300 Ångströms in the true energy spectrum of

Photograph from The World Photos, Inc

SIR ARTHUR EDDINGTON AND PROFESSOR ANTONIE PANNEKOEK

the sun exceeds considerably the amount to be expected for a black body at a surface temperature of 6,000° K.

The Harvard Observatory had its "birthday party" on Friday morning, on which occasion twenty-eight papers by members of the staff were presented. Miss Annie J. Cannon, who has done more work in the classification of stellar spectra than any one else in the world, told about the innovation of the Henry Draper charts of stellar spectra. Dr. Harlow Shapley and Miss C. D. Boyd presented results of a study that revealed for the first time variable stars well beyond the galactic center. Miss H. H. Swope reported on the discovery of a most remarkable variable star that had apparently changed from an irregular variable into a respectable Cepheid variable with a period that has gradually increased from 14 days in 1928 to 21 days in 1936. Dr. F. L. Whipple and Mr. L. E. Cunningham discussed the orbit of the asteroid Apollo, better known in the astronomical vernacular as "Reinmuth's object." This asteroid was only observed for less than a month, and the elongated shape of its orbit would make its rediscovery highly important. The calculations showed, however, that the chances for rediscovery are exceedingly small. Professor J. S Paraskevopoulos, superintendent of the southern station of the Harvard Observatory at Bloemfontein, Orange Free State, South Africa, presented some remarkable photographs of southern nebulae and clusters. Professors D. H. Menzel and J. C. Boyce reported preliminary results of the "Harvard-M.I.T." eclipse expedition to Ak Bulak (USSR), where they found the corona to be at least fifty times as bright as the full moon.

The conferences on Thursday and Friday afternoons were undoubtedly the high points of the meeting. Professor Antonie Pannekoek, of the University of Amsterdam, Holland, told of his work on the interpretation of the continuous spectra of the stars. His paper gave a most lucid exposition of the complex problem of stellar surface temperatures. Professor Henry Norris Russell, of

Princeton University, the president of the American Astronomical Society, gave a summary of his extensive work on the masses of the stars. His investigation confirmed in a remarkable fashion Eddington's pioneer work on the mass-luminosity relation, and he gave important observational evidence bearing upon the hydrogen content of the stars. Dr. Th. Dunham, of Mount Wilson Observatory, discussed his work on the temperatures and pressures of the stars, and one of our most distinguished visitors from abroad, Dr Megh Nad Saha, of the University of Allahabad, told of the importance of studies of the ultra-violet radiation of the sun The final paper of the Thursday afternoon session was presented by Dr Otto Struve, director of the Yerkes and McDonald Observatories, who reported on a series of elegant investigations on reflection nebulae made by himself and his associates. Struve showed from studies of the similarity in color between stars and associated nebulae that Rayleigh scattering plays no rôle, but that sizable particles with diameters of the order of one thousandth of a millimeter are largely responsible for the appearance of the reflection nebulae.

The main events of the Friday afternoon conference on cosmogony were addresses by Professor Tullio Levi-Civita, of Rome, Italy, and Sir Arthur Eddington, of Cambridge, England. Unfortunately illness of his wife prevented Professor Albert Einstein from taking part in this discussion. Professor Levi-Civita had as his topic "Astronomical Consequences of the Relativistic Two-body Problem," and Sir Arthur Eddington spoke about "The Cosmical Constant and the Recession of the Nebulae." Additional short papers were presented by Professor Arthur Haas, of the University of Notre Dame, and Professor H. P. Robertson, of Princeton University.

DRS. SAHA AND SHAPLEY AT THE HARVARD COLLEGE OBSERVATORY

DR. MEGH NAD SAHA, OF THE UNIVERSITY OF ALLAHABAD, EDITOR OF "SCIENCE AND CULTURE," WHO REPORTED UPON HIS RECENT STUDIES OF THE ULTRA-VIOLET RADIATION OF THE SUN; DR. HARLOW SHAPLEY, DIRECTOR OF THE HARVARD COLLEGE OBSERVATORY, WAS HOST TO THE VISITING ASTRONOMERS.

Probably the most exciting event of the meeting took place after the society banquet on Friday evening, when Dr. H. D. Curtis, of the University of Michigan, showed motion pictures of the sun taken at the McMath-Hulbert Observatory at Lake Angelus, Michigan. I doubt very much whether any one present on that occasion would ever have dared to predict that eruptive prominences could change in such a remarkable fashion as that shown by these motion pictures The evident turbulent motion and the "sucking back" of some of the prominences into the solar surface were a most exciting sight. The motion pictures shown by Dr. Curtis had been taken only quite recently and the astronomical world looks forward to hearing about the details revealed upon further study.

The Harvard meeting of the American Astronomical Society was rich in solid contributions, and I feel that it can be fairly said that there has been at no meeting in the past such an indication of abundant astronomical activity in the United States.

BART J. BOK
HARVARD COLLEGE OBSERVATORY

TWO PAPERS IN THE BIOLOGICAL SCIENCES OF THE HARVARD TERCENTENARY CONFERENCE

THE MODE OF OPERATION OF THE "ORGANIZER"

PROFESSOR HANS SPEMANN outlined experiments on the development of amphibian larvae, carried out during the past fifteen years by himself and his associates, which have given much insight into the problem of why a particular region in the early embryo develops into a particular organ in the embryo. When a fertilized egg-cell has only just begun to develop and the future embryo is represented by little more than a mass of cells surrounding a central cavity, there is no obvious sign of dominance of one part over another, but Professor Spemann showed that one particular region, the dorsal lip of the blastopore, determines the formation of the primary axis of the embryo. A tiny piece of tissue transplanted from this region into another part of the same or a different embryo will induce the formation of a second axis of development, and a double embryo will form. This organization of an entire embryo by a little piece of one young germ placed in another is the basis of the original concept of the "organizer." This idea and its experimental development won for Professor Spemann in 1935 the Nobel Prize in physiology and medicine.

Professor Spemann explained that the starting point of this work lay in earlier experiments of the same sort, involving the removal of specific regions of the germ and their replacement by material from another place. If in a very young embryo of the Triton, a newt, a piece of tissue which would normally become brain is removed and replaced by tissue which would normally form skin, the latter does not become skin but brain. The identity of the transplanted and transformed tissue during its development can be proved by taking it from another species containing more or less pigment than the tissues of the host. This shows that in these early stages of development a given bit of tissue may become either skin or brain. Next came the question as to the nature of the influence proceeding from the underlying structures, the so-called mesoderm, which directs the development of the transplant into brain in one case and skin in another. A long series of experiments showed that many substances from animal tissues of the most diverse origins, from tape-worm to man, and even chemically pure substances of known constitution, exhibited this capacity of inducing differentiation. But the discovery of these wide-spread inductive effects exerted by practically every tissue in the growing embryo is only one step in the solution of the problem, for it does not explain why the particular organ develops in its proper place, but only that development of some sort is induced. The answer is to be sought in part in the combination of the various influences from all the neighboring tissues. There is not only one but a whole system of "field-effects," proceeding from various regions, whose interplay determines development.

Professor Spemann further explained that many important factors also reside in the transplanted tissue itself. The stage of development at which the transplant is made may be decisive Apparently at one time a given bit of skin is "loaded" to the highest degree with the ability to produce, let us say, the lens of the eye. If an inductor acts upon it at this moment of highest readiness a lens will be formed, while at a somewhat earlier stage it would have brought forth an embryonic brain. The factors inherent in the transplanted tissue itself appear still more clearly when tissue is transplanted between distantly related species. A piece of skin from the head region of an early toad embryo placed in the corresponding position in a Triton embryo will develop the suckers and the horny jaws characteristic of the toad instead of the corresponding balancing organs and teeth of the Triton.

Evidently, concluded Professor Spemann, the releasing stimulus which induces development must in one respect be of quite specific nature, because it brings forth that which corresponds to the region; in another respect, however, it must be of quite general nature, because, in the case of transplant between species the induced structure arises in the manner which is peculiar to the animal from which the tissue was obtained. Figuratively speaking, whatever command is issued by the inductors of the host, the response is executed by the transplanted tissue in the manner provided by the inheritance of its own species. Concerning the mechanism of this response there is as yet no well-founded conception.

IDIOSYNCRASY TO CERTAIN CHEMICAL COMPOUNDS

As a part of the Harvard Tercentenary Conference of Arts and Sciences, Dr. Karl Landsteiner, of the Rockefeller Institute for Medical Research, who received the Nobel Prize in 1930 for his discovery of the blood groups, presented an address on "Serological and Allergic Reactions with Simple Chemical Compounds."

Dr. Landsteiner has been engaged for many years on a searching study of the chemical reactions and processes underlying immunity. Animals treated with a foreign protein (antigen) develop specific substances (antibodies) which react chemically with the original antigen if it is again introduced into the body. This phenomenon is fundamental to the development of immunity to foreign bacteria. On the other hand, under certain circumstances an animal treated with a minute amount of a foreign protein may be killed on subsequent injection of a small amount of the same substance, after a suitable time interval. This phenomenon is known as anaphylaxis. The biological mechanism underlying both anaphylaxis and immunity is the same, although its manifestations in the two cases are so radically different. Closely related to anaphylaxis is allergy or excessive sensitiveness to foreign proteins, of which the most familiar example is hay fever.

Dr. Landsteiner, who has probably done more than any other living man to elucidate the chemical nature of antigens and their specificity, devoted his lecture to a discussion of sensitivity to simple chemical compounds, and its relation to the general phenomenon of immunity. "The knowledge of exceptional untoward effects of drugs," he remarked, "or disturbances resulting from contact with plants or ingestion of food must be as old as medical experience, and histories of such cases date from early times. But the phenomena of idiosyncrasy, in particular drug idiosyncrasy . . remained wholly inexplicable until the memorable discovery of anaphylaxis . . To all appearances this was a clue to the understanding of drug idiosyncrasy. In both cases very small quantities of otherwise innocuous substances produce severe effects in sensitive individuals, and in both instances the sensitivity is strikingly specific.

"Still," Dr. Landsteiner continued, "there are significant differences between the two conditions which at once seemed irreconcilable and which led many authors to deny any essential relationship." To clear up these discrepancies, studies were made by injecting simple chemicals repeatedly into the skin of guinea pigs. "In this way definite sensitization effects were obtained with numerous and diversified substances . . . As regards regularity the method compares with the standard anaphylaxis experiment and the comparison extends to the specificity of the reactions, the duration of the allergic state and the small quantities of substance, *e.g.*, 1/250 milligram which are sufficient to induce an increase in sensitivity."

After a detailed discussion of the significance of his experiments, Dr. Landsteiner concluded: "It may be taken as established from the foregoing that drug idiosyncrasy, in many instances at least, comes into the same category as anaphylaxis."

H. T. C.

WOODS HOLE MEETING OF THE GENETICS SOCIETY OF AMERICA

DURING the first week in September, the Genetics Society of America held its third summer meeting, which was unusually well attended, at the Marine Biological Laboratory of Woods Hole. Of the total registration of 149, 68 were members and the remaining 81 were non-members. As expected, a fair proportion of the attendance came from biologists who spend their summer at Woods Hole. However, 81 came especially for the meeting. Of these 55 were members and 26 non-members. The largest representation of 18 came from Cold Spring Harbor, N.Y. The conference was attended by an outstanding group of geneticists and cytologists, among whom were Drs. W. E. Castle, Chas B. Davenport, E. M. East, R. A. Emerson, C. E. McClung, T. H. Morgan and E. B. Wilson.

—*Photograph by Bachrach*

DR. P. W. WHITING

PRESIDENT OF THE GENETICS SOCIETY OF AMERICA; ASSOCIATE PROFESSOR OF ZOOLOGY, UNIVERSITY OF PENNSYLVANIA.

The meeting was opened on September 3 with an evening lecture by Professor Th. Dobzhansky, of the California Institute of Technology, on the "Genetic Nature of Species Crosses" and

OFFICERS OF THE GENETICS SOCIETY OF AMERICA
WHICH HELD ITS THIRD SUMMER MEETING AT THE MARINE BIOLOGICAL LABORATORY AT WOODS HOLE DURING THE FIRST WEEK IN SEPTEMBER. *Left to Right* ON THE STEPS OF THE LABORATORY. DR. D. F. JONES; DR L. J. STADLER; DR R. A EMERSON, DR. M. DEMEREC.

by a motion picture film of Professor L. R. Dice, of the University of Michigan, showing some types of waltzing and epilepsy in mice of the genus Peromyscus Dr. Dobzhansky, expanding the usual approach to genetics, said in part: "Organisms are segregated into a finite number of discrete groups, species, which are prevented from interbreeding or exchanging genes with representatives of other similar groups. On the other hand, new gene combinations are constantly arising, due to mutation and hybridization. Evolution may be described as a resultant of interaction of two opposing groups of forces: those tending toward fixation of established gene patterns with proven survival value and those tending to the production of new gene patterns. Fixation is accomplished by a variety of 'isolating mechanisms' preventing free interbreeding." The program consisted of the two morning sessions of round table discussions, each of which was attended by about 160. At each of these sessions the subject was briefly introduced by two speakers, after which followed a general discussion. The first session dealt with "Progress in Cytogenetics," and the second conference with the "Nature of Mutations." The Friday afternoon session was devoted to the presentation of 26 demonstration papers.

M. DEMEREC

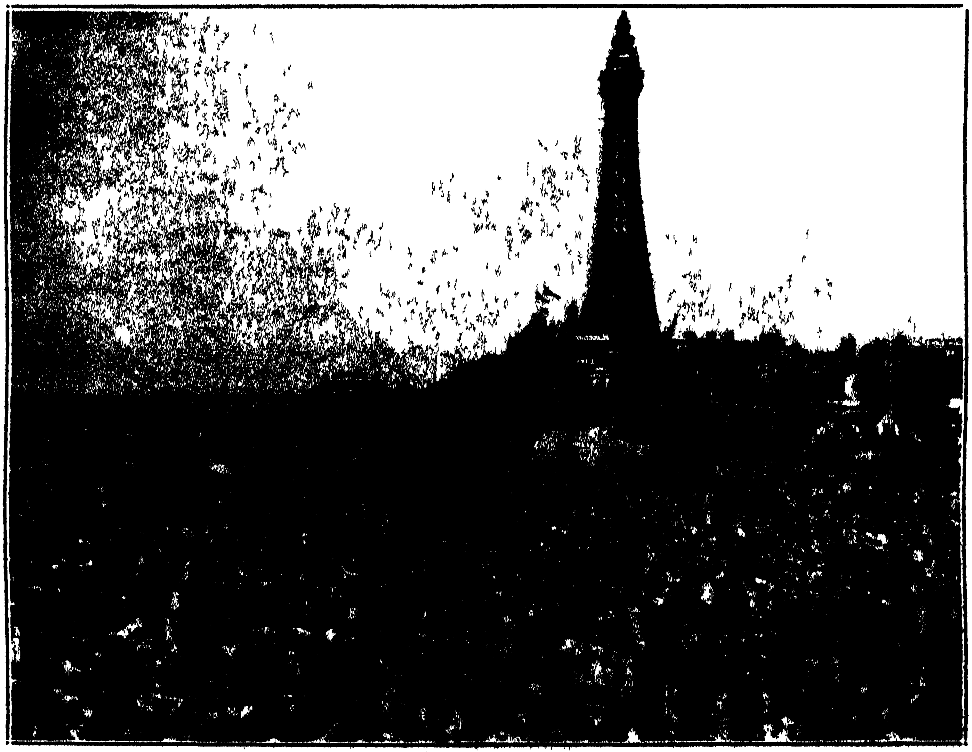
THE BRITISH ASSOCIATION AT BLACKPOOL

Two of the greatest scientific groups in the world scheduled their 1936 meetings at famous amusement centers. The British Association for the Advancement of Science convened in the week from September 9 to 16 at Blackpool, a holiday resort in the "north-country" of England, while the American Association is to meet at Atlantic City during the Christmas vacation period.

Blackpool has been termed by Sir Josiah Stamp, president of the British Association, "the world's greatest center of mass amusement and gaiety." The choice of this meeting place was but a phase of the subtle plan underlying the 1936 meetings, the application of science to human affairs. There was a distinct trend in the sectional meetings toward discussions and joint meetings dealing with the relations between science and society rather than isolated papers. The public lectures, delivered in neighboring districts, had a decided popular appeal.

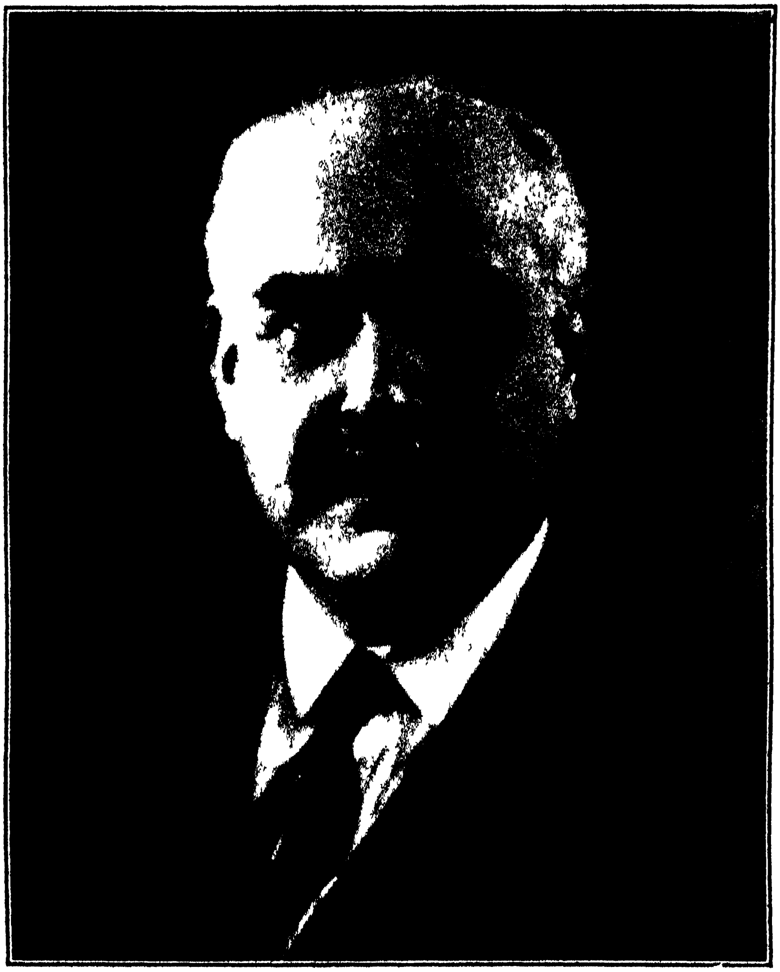
The meetings opened on September 9 at the Empress Hall, Winter Gardens, as Sir Josiah Stamp delivered the presidential address, "The Impact of Science on Society." Two evening discourses were presented to the entire group, Mr. C. C. Paterson on "Science and Electric Lighting," and Captain F. Kingdon Ward on "Plant-hunting and Exploration in Tibet." Following the lecture by Mr. Paterson, the members appropriately had an opportunity to witness the annual autumn illumination of the sea-front, which has increased in splendor yearly during the past fifty years.

The more formal portion of the divi-



THE BEACH AT BLACKPOOL, ENGLAND

VIEW FROM THE CENTRAL PIER, SHOWING THE FAMOUS BLACKPOOL TOWER IN THE BACKGROUND.



SIR JOSIAH STAMP, G.C.B., G.B.E.,
PRESIDENT OF THE BRITISH ASSOCIATION

sional programs consisted of addresses by the presidents of the various sections. In the mathematical and physical sciences, Professor Allan Ferguson, on "Trends in Modern Physics"; chemistry, Professor J. C. Philip, on "The Training of the Chemist for the Service of the Community"; biology, Professor H. L. Hawkins, on "Paleontology and Humanity"; zoology, Dr. Julian Huxley, on "National Selection and Evolutionary Progress"; geography, Brigadier H. S. L. Winterbotham, on "Mapping of the Colonial Empire"; economic science and statistics, Dr. C. R. Fay, on "Some Aspects of Commercial Agriculture"; engineering, Professor W. Cramp, on "The Engineer and the Nation"; anthropology, Miss D. A. E. Garrod, on "The Upper Paleolithic in the Light of Recent Discovery"; physiology, Professor R. J. S. McDowall, on "Integration in the Circulation"; psychology, Mr A. W. Wolters, on "Patterns of Experience"; botany, Mr. J. Ramsbotham, on "The Uses of Fungi"; education, Sir Richard Livingstone, on "The Future in Education"; agriculture, Professor J. Hendrick, on "Soil Science in the Twentieth Century."

The association this year inaugurated a policy in the sectional meetings of "starring in the program those items which deal with aspects of knowledge the repercussions of which on the welfare of the community are direct and important" Starred discussion sessions included those on high voltages, textiles, chemistry and the community, scientific problems of the poultry industry, climate and health, botany and gardening, social and cultural value of science, national nutrition and British agriculture, the strain of modern civilization, Abyssinia and engineering problems of mass-amusement Discussions not starred dealt with genetics and the race concept, education for rural life, motor-car headlights, sea defences, agricultural geography of the Fylde, earth movements in northeast England and the physical basis of living matter.

The public lectures at outlying Blackpool South, Lytham St Annes, Poulton-le-Fylde, etc., included Dr Olaf Bloch, on "The Scope of Photography"; Dr. W. F. Bewley, on "Science and the Glasshouse Industry"; Sir James Jeans, on "Some Recent Advances in Astronomy"; Professor Allan Ferguson, on "Splashes and What They Teach"; Professor C. M. Yonge, on "Common Shore Animals"; Professor J. L Myres, on "Who Were the Greeks?" and others. The appeal of the meetings was made universal by the inclusion of a special series of lectures for school children.

Besides the unscheduled visits to the nearby amusement park and the open-air swimming bath, thirty sectional excursions of scientific and educational interest were undertaken by members of the association, including expeditions to Garstang, Furness Abbey, the Southport Sand Dunes, Fleetwood Fish Docks, Fylde Farms, the Metropolitan-Vickers Works at Manchester, the Potato-testing Station at Ormskirk and the Mussel-cleaning Station at Lytham

Sir Josiah Stamp, president of the association, is a world-known economist and chairman of the London, Midland and Scottish Railway. He has served on many committees relative to national and international economics, including the Dawes committee on German currency and finance in 1924 and the Paris committee of inquiry into the reparations question of 1929. "Wealth and Taxable Capacity," with editions in 1922 and 1923, is one of the best known of his books. He has received the honorary degrees of doctor of science from Oxford and Cambridge and the degree of doctor of laws from Harvard University.

CORRESPONDENT

THE SCIENTIFIC MONTHLY

NOVEMBER, 1936

HARVARD TERCENTENARY CONFERENCE OF ARTS AND SCIENCES

ADDRESSES GIVEN AT HARVARD UNIVERSITY IN SEPTEMBER, 1936

CONSTITUTION OF THE STARS

By Sir ARTHUR STANLEY EDDINGTON
PROFESSOR OF ASTRONOMY, UNIVERSITY OF CAMBRIDGE

WHEN we turn a telescope on the sun, we look at it through its tenuous envelopes—the corona and chromosphere—then down through a few hundred kilometers of its outermost atmosphere, to a level where it becomes too opaque for us to see further, just as, in looking down on the ocean, we can see down a few feet but no further. At the vaguely defined level which is the limit of our vision, the temperature is about 6,000°. What lies below that level? What is it like deep down in the interior of the sun—and the other stars?

The exploration of the deep interior of the stars began in 1869 with a paper by Homer Lane of Washington, which he entitled, "On the Theoretical Temperature of the Sun, under the Hypothesis of a Gaseous Mass, Maintaining its Volume by its Internal Heat and Depending on the Laws of Physics as Known to Terrestrial Experiment." Evidently he didn't believe in snappy headlines. This paper has been the foundation of developments by Ritter, Emden and others, which are being continued at the present day.

There is a phrase in the title of Lane's paper which I would underline: "*Depending on the laws of physics as known to terrestrial experiment.*" That expresses the principle of which I profess myself a devotee. We want to find out how far the phenomena which we observe in the sky agree with, and are a consequence of, the laws that have been assigned to matter as the result of terrestrial experiment. Take ordinary matter—some mixture of the elements that we know—and apply on a large scale the properties of matter and radiation that have been found by experiments on a small scale. Treat it as though you were designing a large dam instead of a large star—with just the same kind of calculations and exercising so far as possible the same kind of foresight. The conditions in the star are very extreme; but the ultimate things to be dealt with—electrons, atomic nuclei, x-rays—are the same in the star as in the laboratory, and we can apply our laboratory knowledge of them. Calculate in this way what will be the properties of the huge mass—what, for example, will be its output of heat and light, what will be its period if it is set pulsating. Calculate "according to the laws of physics as known to terrestrial experiment"; and then turn to the man with the telescope and ask, "Is that anything like the stars *you* come across in the sky?" It may be that he will point out differences. If the stars have anything new to reveal to us—which the physicist with his limited conditions of experiment has been able to foresee—we shall in this way sort it out from that which is a direct consequence of what we already know or think we know.

Investigations which follow this course of procedure are clearly not speculative. However faulty and uncertain they may be, they keep to the pedestrian path of progress and eschew flighty conjecture. Parenthetically, may I ask whether it is not possible for critics of theoretical investigations of the stars to find some other term of disapprobation than the term speculative; one prefers to have even one's faults called by the right name. I don't class all speculation as a fault; and it has sometimes happened that important advances have begun in a speculative way. The real harm is when speculative attempts are not sufficiently discriminated from the straightforward application of existing knowledge; and the converse is no less harmful—when Lane's pattern of investigation, that is to say, the results of applying on the stellar scale the laws found in the laboratory, is confused with the frankly speculative theories that have at times been put forward; and, perhaps I may add for the benefit of the mathematicians here, worst of all, when stars constituted of matter obeying the laws of physics, so far as they have been unraveled to-day, are confused with mathematical creations whose only claim on our attention is that they satisfy elegant differential equations.

I will not guarantee that the conclusions that I shall put before you will survive the progress of knowledge in the next fifty years. If by then the stars of gaseous constitution which we accept today have given place to liquid stars or solid stars or, as I once suggested, crystalline stars composed of *gaseous* crystals—well, there have been more surprising changes in science than that. But I believe firmly that the conclusions are such as fit our present scientific knowledge; and that they represent present-day astronomy in step with present-day physics. To use a rather favorite word nowadays, *unification,* the interest of these investigations is, I think, not so much dependent on the absolute information they yield, as in the unification of physics and astrophysics—enabling us to see one underlying cause or one elementary equation at the root of the most diverse manifestations, tracing its effects in the vacuum tube, in the interior of star, in the diffuse nebulae, and—not least—the system of galaxies which constitutes the cosmos.

I want to leave time to speak of recent problems, so I will run over rather briefly the older part of the subject. Let us suppose that by observation from outside we have ascertained the mass M and the radius R of a star—just those two data. Armed with this information, what can we deduce (by laws of physics) about its interior?

The first difficulty is that, although we have ascertained the total mass, we have not found how it is distributed—whether it is fairly uniform throughout the volume of the star or strongly concentrated to the center. I won't stop to explain how we have got over this difficulty; but it is a side of the problem in which considerable progress has been made in the last year or two. Although we can not determine the concentration accurately, we can assign limits by purely theoretical deduction. The central density is not less than five times the mean density, and not more than fifty times the mean density—so that we know roughly the degree of concentration that we are up against.

Knowing then how the mass is distributed in the structure we can calculate the pressure at any depth. Any civil engineer will tell you that that is possible, so that we know the pressure as well as the density at each point in the interior. Now the density, pressure and temperature are connected by a relation called the *equation of state* of the material; if any two of them are known we can find the third. In this case we know the pressure and density and we can therefore find the temperature—which is, of course, an extremely important thing to find out—in order to realize the sort of conditions we have to deal with. For all the stars except white dwarfs, the equation of state, which connects the temperature with the pressure and density, is the well-known equation of a perfect gas. For the extremely dense matter in white dwarf stars the equation is more complicated; but the theoretical physicist by his terrestrial studies has worked out for us the required equation. (Incidentally he has worked it out wrong—but that is another story, and I'll speak about the white dwarfs later. For the present we will keep to the ordinary stars.)

The internal temperatures determined in this way are of the order 10 to 20 million degrees Centigrade. Having ascertained this, we begin to realize the state of things that we have to deal with. At this temperature all the atoms will be highly ionized. Light elements such as oxygen will be stripped bare to the nucleus, and heavy elements such as iron and lead will retain only a few of the innermost satellite electrons. The rest of the electrons will be free. We have therefore to deal with a population consisting of free electrons, the shattered remnants of atoms and photons or quanta of radiation. Planck's law determines both the amount and kind of radiation present at a given temperature. At 10 to 20 million degrees the radiation consists of rather soft x-rays.

Now, we can see more or less what is happening at 10 million degrees in the interior of the sun. Crowded together within a cubic centimeter there are more than a quadrillion atoms, about twice as many free electrons and 20,600 trillion x-rays (British reckoning). The x-rays are traveling with the speed of light, and the electrons at 10,000 miles a second. Most of the atoms are hydrogen atoms or rather, since they have lost their satellite electrons, simply protons traveling at 300 miles a second. Here and there there will be heavier atoms such as iron lumbering along at 40 miles a second. I have told you the speeds and the state of congestion of the road; and I will leave you to imagine the collisions. Small wonder if the atoms are found with their garb of electrons badly torn or even stripped naked.

The stripped atoms are continually capturing free electrons and, so to speak, repairing their dress; but scarcely has the captured electron settled when an x-ray bears down on it and explodes it away. This is not a fanciful picture. These are phenomena which have been found happening in the laboratory when we use x-rays of the same wave-length and electrons of the same speed as in the sun. There is no need to go beyond the limits of terrestrial experiment to discover what is happening to the population, and all the calculations have an experimental basis.

The atoms and electrons are rushing violently hither and thither; but on the whole they do not get any "forrarder"; gravitation pulls them back and keeps the material of the star in equilibrium. But the x-rays gradually leak outwards. They are subject to gravitation, it is true; but their velocity of 186,000 miles a second is sufficient for escape from any star. It is just the same as in the theory of planetary atmospheres, where gravitation is sufficient to retain the heavier constituents, but the lightest atoms have sufficient velocity to escape. The planet thus loses the lightest gases; and in the same way the star loses (or, as we say, radiates) photons of radiation. I should explain that, although these photons are x-rays in the interior of the star, they are transformed down to longer wavelength in passing through the last few thousand kilometers of comparatively cool matter; so that it is in the form of light and heat waves that they finally escape.

So you may picture a photon of radiation, barging first one way, then another, like a man in a rioting mob—absorbed by an atom and flung out again in a new direction. In this way a photon in the sun will wander aimlessly round in the interior for a million years or more until, just by accident, it finds itself at the exit of the maze—shoots through—and makes a bee-line across space to the Oakridge reflector, where Professor Shapley photographs it.

Having first ascertained the particulars about the population that I have been describing, we can apply the laws (based on laboratory experiment) which determine the amount of obstruction offered by atoms and electrons to the passage of x-rays, and so find how many photons leak out into space per second. We can compare this result with observation—that is to say, we can see whether Professor Shapley catches as many of them with his telescope as (according to our calculation) he ought to catch—in short, whether the star is actually as bright as our calculation makes it.

In the last few years we have found a complication in the calculation which I must now explain. At an earlier stage we had to ask the physicist to supply a formula giving the temperature of a gas when the pressure and density are known. Not unreasonably he will object: "You have not given me enough information. What *is* the gas?—oxygen? iron vapor? mercury vapor? or what? We can not say."

But on second thought he withdraws the objection. "Never mind. Ordinarily it would make a big difference, but at the high temperatures we are concerned with it makes practically no difference what element we take. The atoms will be almost completely ionized; that is to say, their satellite electrons will be moving as free particles. We only want to know the average weight per free particle. The number of satellite electrons in an atom is roughly half the atomic weight—so that we shall have roughly 2 units of weight per particle, for example, oxygen. Owing to this remarkable property it has been possible to make considerable progress with the theory of the interior of a star without knowing what chemical elements it is composed of."

Those are the physicist's second thoughts. But on third thought he exclaims, "Bother! There's hydrogen." The rule that there are two units of weight per particle does not work for hydrogen. It has atomic weight 1 and splits up into a proton and electron so that the average weight per particle is ½—instead of 2. That makes a vast difference.

A year or two ago the physicist had some alarming fourth thoughts about neutrons; but neutrons are absorbed very easily by atomic nuclei and I think they will have only a transitory existence on the sun, as on the earth, and never form an appreciable part of the population—so we won't worry about fourth thoughts. The crux of the matter is that, for the purposes of these investigations, there are just two kinds of matter, namely, *hydrogen* and *not-hydrogen*. Hydrogen gives a much lower temperature than *not-hydrogen*, and therefore lower brightness for a star of the same mass and radius. Our comparison of theory and observation can therefore be used in two ways. We can calculate the brightness of a star, assuming the material to be *not-hydrogen*, compare it with observation, congratulate ourselves on the partial agreement we find, and ponder over the possible sources of the discrepancies which remain—one possible source of discrepancy will be the presence of a significant proportion of hydrogen. The other way is to try various combinations of hydrogen and not-hydrogen until we find the proportion which gives precise agreement of the calculated and observed brightness. That is the method we generally employ nowadays; the observed brightness of a star tells us what proportion of its mass consists of hydrogen.

Dr. Bengt Strömgren found in this way that the sun, Capella and other typical stars contain 33 per cent. of hydrogen. My own calculations agreed precisely. This agreement is rather specially interesting because we adopted different composition for the remaining 66 per cent. of the mass. Strömgren used a mixture of rather light elements, familiarly known as "Russell's Mixture," believed to agree with the composition of the outer layers determined with the spectroscope; I used a mixture about three times heavier. Our precise agreement confirms what I have already said—that it makes no difference what kind of stellar material you assume—so long as it is *not-hydrogen.* It is still doubtful to what extent the proportion of hydrogen varies in different stars; there is some evidence that it is greater in the most massive stars, but the evidence is not very good. An important paper presented by Professor H. N. Russell to the Tercentenary Conference was partly devoted to this question.

I must say a word about the agreement of theory and observation. Since we determine the proportion of hydrogen so as to make the observed and calculated brightness agree, we obviously can not claim that the agreement is a confirmation of the theory. Nevertheless it does furnish a fairly efficient check. Unless the theory were pretty near the truth we should find that for some of the stars which we try, it would be impossible to find any proportion of hydrogen that would bring about agreement. It is satisfactory therefore that all the stars give a reasonable proportion. If Strömgren had found, instead of 33 per cent., an answer which involved the square root of -1, as might easily have happened, we should have concluded that there was something fishy about the theory.

The recognition of white dwarf stars with density far transcending that of any terrestrial matter is one of the more spectacular developments of the study of stellar constitution. A cubic inch of the matter of the companion of Sirius weighs about a ton and some of the more recently discovered white dwarfs appear to have higher densities even than that. In order to explain a new point which has arisen in connection with the theory of these stars, I must go back to past history. In 1924 the mass-luminosity relation—that is, the formula expressing the result of the calculation I have been describing—was worked out; and, on comparing with observation, it turned out that it was obeyed not only by the diffuse giant stars for which it was intended but also by the dwarf stars with densities greater than water for which it was *not* intended. This was a complete surprise. But the explanation was not difficult to find. We had been taking it for granted that stellar matter would cease to behave as a perfect gas when the density approached that of ordinary liquids or solids. Ordinary terrestrial atoms then begin to jam together and the material becomes almost incompressible. But in the stars the temperature of 10 million degrees causes most of the satellite electrons to be stuffed away from the atom, and what is left of the atom is a tiny structure. The atoms or ions are so reduced in size that they will not jam until densities 100,000 times greater are reached. For this reason, the perfect gas state continues up to much higher densities in the stars. The sun and other dense stars insisted on obeying the theory worked out for a perfect gas, as they had every right to do, since their material was perfect gas.

There was therefore nothing to prevent stellar matter from becoming compressed to exceedingly high density; and it suggested itself that the densities which had been calculated from observation for certain stars called white dwarfs, which had seemed impossibly high, might be genuine after all.

In reaching this conclusion I was not without a certain misgiving. I was uneasy as to what would ultimately happen to these super dense stars. The star seemed to have got itself into an awkward fix. Ultimately its store of subatomic energy would give out and the star would then want to cool down. But could it? The enormous density was made possible by the high temperature which shattered the atoms. If it cooled it would presumably revert to terrestrial density. But that meant that the star must expand to say 5,000 times its present bulk. But the expansion requires energy—doing work against gravity; and the star appeared to have no store of energy available. What on earth was the star to do if it was continually losing heat, but had not enough energy to get cold!

The high density of the companion of Sirius was duly confirmed by Professor Adams—but this puzzle remained. Shortly afterwards Professor R. H. Fowler came to the rescue in a famous paper, in which he applied a new result in wave mechanics which had just been discovered. It is a remarkable coincidence that just at the time when matter of transcendently great density was discovered in astronomy, the mathematical physicists were quite independently turning attention to the same subject. I suppose that up to 1924 no one had given a serious thought to abnormally dense matter; but just when it cropped up in astronomy it cropped up in physics as well. Fowler showed that the newly discovered Fermi-Dirac statistics saved the star from the unfortunate fate which I had feared.

I will say a word or two about Professor Fowler's explanation. My colleague Fowler was in his youth a pure mathematician, and I am afraid he has never really recovered from this upbringing. Consequently, although his paper contained reassuring equations, it did not clearly reveal the simple physical modification of ideas which wave mechanics brought about. He proved that the star would manage all right. But, as you may have inferred from Professor Hardy's revelations, I am not an extreme worshipper of proof. I want to know *why;* a proof does not always tell you that. As Clerk Maxwell used to ask, "What's the go of it?" Well, in this case the "go of it" was that whereas the older theory said that atoms could only be ionized by high temperature the new wave mechanics said that high temperature was not essential because they could also be ionized by crushing them under high pressure. Several writers tumbled to it, before I did, that that was what Fowler's rather mysterious result really meant; but I think that it is still not at all generally known. You see this allows the star to cool down and still retain its enormous density—which the older classical physics did not.

Not content with letting well alone, physicists began to improve on Fowler's formula. They pointed out that in white dwarf conditions the electrons would have speeds approaching the velocity of light, and there would be certain relativity effects which Fowler had neglected. Consequently Fowler's formula, called the *ordinary* degeneracy formula, came to be superseded by a newer formula, called the *relativistic* degeneracy formula. All seemed well until certain researches by Chandrasekhar brought out the fact that the relativistic formula put the stars back in precisely the same difficulty from which Fowler had rescued them. The small stars could cool down all right, and end their days as dark stars in a reasonable way. But above a certain critical mass (two or three times that of the sun) the star could never cool down, but must go on radiating and contracting until heaven knows what becomes of it. That did not worry Chandrasekhar; he seems to like the stars to behave that way, and believes that that is what really happens. But I felt the same objections as twelve years earlier to this stellar buffoonery; at least it was sufficiently strange to rouse my suspicion that there must be something wrong with the physical formula used.

I examined the formula—the so-called relativistic degeneracy formula—the conclusion I came to was that it was the result of a combination of relativity theory with non-relativistic quantum theory. I do not regard the offspring of such a union as born in lawful wedlock. The relativistic degeneracy formula—the formula currently used—is in fact baseless; and, perhaps rather surprisingly, the formula derived by a correct application of relativity theory is the ordinary formula—Fowler's original formula which every one had abandoned. I was not surprised to find that in announcing these conclusions I had put my foot in a hornet's nest; and I have had the physicists buzzing about my ears —but I don't think I have been stung yet. Anyhow, for the purposes of this lecture, I will assume that I haven't dropped a brick.

I venture to refer to a personal aspect of this investigation, since it shows how closely different branches of science are interlocked. At the time when my suspicion of the relativistic degeneracy formula was roused by Chandrasekhar's results it was very inconvenient to me to spare time to follow it up because I was immersed in a long investigation in a different field of thought. This work, which had occupied me for six years, was nearing completion and there remained only one problem, namely, the accurate theoretical calculation of the cosmical constant, needed to round it off. But there I had completely stuck. I had, however, secured a period of four months free from distractions which I intended to devote to it—to make a supreme effort, so to speak. But having incautiously begun to think about the degeneracy formula I could not get away from it. It took up my time. The months slipped away, and I had done nothing with the problem of the cosmical constant. Then one day in trying to test my degeneracy results from all points of view, I found that in one limiting case it merged into a cosmical problem. It gave a new approach to the very problem which I had had to put aside—and from this new approach the problem was soluble without much difficulty. I can see now that it would have been very difficult to get at it in any other way; and it is most unlikely that I should have made any progress if I had spent the four months on the direct line of attack which I had planned.

The paper which I read before the Harvard Tercentenary Conference of Arts and Sciences, giving a calculation of the speed of recession of the spiral nebulae and the number of particles in the universe, had an astronomical origin. It was not, however, suggested by consideration of the spiral nebulae. It arose out of the study of the companion of Sirius and other white dwarf stars.

I mentioned that we only gradually came to realize that ionization could be produced by high pressure as well as by high temperature. I think the first man to state this explicitly was D. S. Kothari. Stimulated by some work of H. N. Russell, Kothari has made what I think is an extremely interesting application. The relation of ionization to pressure is a curious one, for at low pressures we decrease the ionization by increasing the pressure; but the ionization must have a minimum, for at high pressures the Fermi-Dirac complication steps in and the ionization ultimately increases with pressure. No one seems to have bothered much about this revised ionization law; they have been content to recognize or I think rather to guess that in white dwarfs the ionization would be pretty high Kothari, however, has treated it seriously and worked out the degree of ionization in various conditions, including comparatively small masses in which the pressure is relatively low and the ionization is not very high.

I turn now to the subject of subatomic energy which we believe to be the source which maintains a star's heat. This is a matter on which, until about three years ago, terrestrial experiment gave us no help at all. Conditions have now changed, and physical laboratories throughout the world have given themselves up to an *orgy of atom-splitting.* It is of immense importance for the future of astronomy that a new laboratory technique enables us to experiment directly on the processes of liberation of energy by transmutation of atomic nuclei, since these are almost certainly the processes which keep the stars alight. But at present it is too early to expect results this way. The theory of stellar constitution, which I have been describing, was built up without any laboratory knowledge of a sub-atomic energy. This was possible because the problem of the source of maintenance of a star's heat could be segregated almost completely from the rest of the problem. By Lane's method we could determine the temperature—how much heat there was in the star—without speculating as to how it came to be there; and we could show that a star so endowed must radiate at the moment a calculable amount of light and heat—without inquiring how it managed to go on radiating it for thousands of millions of years. In short, the structural problem could be segregated from the evolutionary problem.

The only point at which the segregation is not complete is this: The concentration of density towards the center of a star depends to some extent on how the source maintaining the heat is distributed. It seems clear from present-day experiment, as well as from astronomical evidence, that the liberation of sub-atomic energy increases rapidly with temperature; so that we may expect it to occur mainly in the hottest central part of the star. This has the effect of diminishing the concentration of density to the center—making it less than in the standard model which has generally been employed. This effect is, however, limited; because if the star overdoes it convection currents are set up, which bring about compensation. To describe our present conclusion I must use technical terms: The density distribution near the outside has a polytropic index 3 which gradually diminishes to 1.5 at the center, where there is a convective core I am speaking of ordinary stars such as the sun; but curiously enough this specification of the density distribution applies also to white dwarfs—for which it has long been the recognized model—though in the white dwarfs it comes about in quite a different way.

Apart from this refinement, the researches which I have hitherto described are not affected by theories of sub-atomic energy. But they put us in a favorable position to learn something about the laws of sub-atomic energy. Many well-known lines of argument have convinced us that the sun and stars have a lifetime to be reckoned in thousands of millions of years—which means that evolutionary changes are extremely slow and that the heat radiated by a star into space is almost exactly balanced by the heat liberated from sub-atomic sources in the interior. So when we measure the radiation of a star, we measure the generation of sub-atomic energy. You see then that the measurement of sub-atomic energy is just a common everyday astronomical measurement.

To the engineer the release of sub-atomic energy on a practical scale is, and seems likely to remain, a Utopian dream To the physicist it was, until three years ago, a field of uncontrolled theoretical speculation To the astronomer it has long been an every-day phenomenon which it would be absurd to close his eyes to

Having then measured the rate of release of sub-atomic energy in all types of stars, we can correlate it to the temperatures and densities which we have found in the interior. This more or less direct investigation of the conditions of release can be supplemented by a theoretical examination of the conditions of stability of stars containing such a source —a line of attack initiated by Professor H. N. Russell.

If the star contracts, the liberation of sub-atomic energy must be stimulated; otherwise the star is unstable. We can not deduce astronomically whether the stimulus comes from the increased temperature or the increased density; but for simplicity we shall suppose it to be mainly the temperature. Then each star contracts until its internal temperature reaches the value at which the liberation of sub-atomic energy the heat radiated and there it sticks—not quite indefinitely but for a very long period until the sources of sub-atomic energy show signs of exhaustion. The stars on the main series appear to be those which have reached this balance and stuck. Now it is one of the results of our previous investigations that the stars of the main series, from the most massive to the lightest, have practically the same internal temperature. We used to give the central temperature as 40,000,000°, but the figure has come down—partly by the recognition of the abundance of hydrogen and partly by the substitution of a less condensed model, and the present estimate is about 15 million degrees. But whatever it is, it is nearly the same for all. It appears therefore that on the main series a small star which requires a small amount of energy per gram to maintain its radiation and a massive star requiring 1,000 times as much energy per gram both have to rise to 15 million degrees to liberate. Or to put it another way the liberation must increase 1,000 fold in a rise of temperature scarcely large enough for us to notice in our rather rough calculations.

Another result of the examination of the stability of a star is important. The rate of liberation of sub-atomic energy must increase with temperature but not too fast; if it increases more steeply than a certain limit the star will be thrown into pulsation. Some stars do pulsate, namely, the Cepheid variables, but the majority do not. Perhaps we may infer that the actual law of increase is pretty near the limit, so that the conditions of most of the stars are on the one side and those of the Cepheids just beyond it. But there is a way by which the star can escape this pulsatory instability. We have been supposing that the response of the sub-atomic energy to the stimulus of temperature is immediate; if there is a lag—if the rising temperature stimulates the formation of active material which emits the energy later on in its own good time, or if it starts a chain of processes of which the actual energy liberation is the last, then there will be no pulsation. A lag of some days at least is required. Provided there is this lag, the stars will be stable, even though the energy—liberation increases very rapidly with the temperature—as our observational results for the main series stars indicate and as is also indicated by the recent laboratory experiments.

This is the main information about

sub-atomic energy that we have learned from astronomy. I suppose that, taken altogether, it seems a meager amount. But its importance is considerably enhanced, when we recall that on almost every point it was completely at variance with the views then held by physicists. The only form of liberation of subatomic energy with which the physicist was then acquainted was that of the radio-active elements—a process independent of density and unaffected by temperature unless the temperature was far higher than 15 million degrees; and he was inclined to be intolerantly disposed towards considering any other process, no matter how strong the astronomical evidence might be. I can not but think that this is an instance of the harm done by the writers who give the impression that stellar investigation is a field of loose speculation. Physics and astrophysics are one subject, following the same rules of progress, recognizing the same standards of rigorous deduction, and utilizing the same corpus of accepted knowledge; and liable to the same failures through our human limitations.

Various attempts were made to find a loophole for admitting much higher temperatures in the stars so as to satisfy the physicist's objection to admitting energy liberation controlled by low temperature; for example, Jeans's theory of elements of very high atomic weight, and Milne's theory of the existence of a core of white dwarf density in ordinary stars like the sun. We can scarcely say that such suggestions are impossible without attributing to our existing knowledge of the laws of physics greater completeness than we care to claim. But I think it can be said firstly that these theories were found on examination not to fulfil what was initially claimed for them—on the strength of which they were recommended. And secondly it is not unfair to describe them as agreeing with the physicist on a matter as to which he knew nothing at the expense of disagreeing with him on matters as to which he claimed to know a great deal.

All that has changed now that these sub-atomic processes have been studied in the laboratory. They are found to require comparatively low speeds of the particles, corresponding to comparatively low temperatures, such as the stellar investigations had indicated. The first criticism I heard, after the experiments on disintegration of elements by protons had begun, was that 40 million degrees was too high a temperature for the sun; and it could not be much over 15 million degrees without blowing up. Happily we had been beforehand; and the revised astronomical calculations already lowered the temperature to a point which makes the sun safe for posterity.

New experimental discoveries have helped us to come to an important decision as to the nature of the sub-atomic energy released in the stars. For fifteen years we have been hesitating between two alternative suggestions. The energy might be provided by electrons and protons annihilating one another, thus setting free the whole energy of their constitution in the form of radiation. Or it might be provided by transmutation of the elements. Even in this application it remains true that we need distinguish only two kinds of stellar matter, namely hydrogen and not-hydrogen; so the transmutation can be more precisely defined as the transmutation of hydrogen into not-hydrogen. The annihilation of a proton by an electron corresponds to the complete disappeaance of a hydrogen atom. The energy released by the transmutation of a hydrogen atom into other elements is only about 1/120 of the energy which would be released by its complete disappearance. Thus the annihilation hypothesis provides more than 100 times as much energy as the transmutation hypothesis; and the possible lifetime of a star is correspondingly increased.

Attempts to decide between the two alternatives by astronomical evidence were inconclusive. But recent progress in physics seems to point decidedly to the transmutation hypothesis; and the annihilation hypothesis seems to have been generally abandoned. Perhaps the most serious blow to it was the discovery of the positron by Anderson at Pasadena. The positron, not the proton, is the true opposite of an electron; and positrons and electrons *do* annihilate one another. Our lust for slaughter being thus satisfied, it would be incongruous to bring in the proton as an alternative agent; and we look on the supposed annihilation of electrons by protons as a rather misdirected anticipation of the real cancelling.

Simultaneously the very long time-scale, which corresponds to the annihilation hypothesis, had lost its attractiveness. The phenomenon of the expansion of the system of the galaxies which constitutes our universe, as well as studies of the stability of individual galaxies, make it difficult to assign an age to the stars greater than 5,000 million years. The radiation required for this period is amply provided for by the transmutation hypothesis, and the hundred fold greater energy provided by the annihilation hypothesis would only be an embarrassment.

Both hypotheses were originally theoretical suggestions; but the transmutation hypothesis can now claim a definite observational basis. Take the sun, which we have found to be ⅓ hydrogen and ⅔ not-hydrogen. At 15 million degrees the hydrogen is ionized and its nuclei—*i.e.*, the protons—are traveling at average speeds of 500 miles a second. We know that in the laboratory protons of this speed attack and enter the nuclei of other elements—the not-hydrogen—and bring about transmutations in them. We may hope that in due time the physicists will be able to trace for us the whole sequence of changes direct and indirect which result, so that we shall be able to find quantitatively the rate of disappearance of free hydrogen under these conditions, and so find the amount of sub-atomic energy of this kind liberated in the sun. If it is found to agree with the sun's rate of radiation, we shall then have definite proof that no other source—such as annihilation—is operative. We are, of course, far from having the necessary knowledge at present. It is complicated by the fact that, although the protons enter atomic nuclei and change the nuclei into new elements, in many cases the new nucleus breaks down after a short time, a proton is shot out and no permanent transmutation results. Such permanent transmutation as is observed comes at the end of a chain of processes of which the attack of the proton on the nucleus was the first. It is interesting to notice that this was already foretold by the astronomical investigations which, as I have said, demand a time-lag between a stimulation of the activity of the protons by rise of temperature and the corresponding increase of output of sub-atomic energy.

I have given you my impression of the way in which this new knowledge works in with, and so far as we can see, agrees with the existing theory of stellar constitution; not because I lay stress on the rough conclusions that can be drawn in the turmoil of new discovery—the data available at present are far too scrappy—but because I want to show how intensely important the work of atom-splitting now in progress is for astronomical developments—so that we may look forward to great developments in the future.

RECENT FINDINGS IN COSMIC-RAY RESEARCHES

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Cosmic rays were christened[1] in 1925 when convincing evidence had been found that they could not have their origin either in the nearer or the remoter portions of our atmosphere, nor yet in the sun or visible stars, but rather came from remoter regions and were distributed essentially uniformly over the celestial dome. At that time it was natural, if not inevitable, that one attempted to compute their energy from the enormous penetrating power which they were then found to have in snow-fed lakes. For this computation it was also natural, if not inevitable, that one use the known laws of absorption of x- and gamma-rays, which laws were based upon the principles of extra-nuclear electronic absorption. It was only when in 1930 Chao[2] first brought clearly to light that with energies above two million electron-volts the nucleus begins to play not an insignificant but a very important rôle in absorption phenomena, that one realized the complete inadequacy of laws like that known as the Klein-Nishina law, for handling the absorption of high energy rays. One was clearly forced to make *direct energy measurements* by the cloud-chamber technique before he could hope to obtain any real knowledge of cosmic-ray energies. This need was first met in 1931 when Anderson, Millikan and Neddermeyer by such directly observed[3] deflectibilities in a magnetic field pushed the definitely measured energies of cosmic rays up to 6 billion electron-volts and found a few particles of energies which were estimated to be not less than 15 billion electron-volts. These measurements showed that Millikan's earlier assumption that the whole of the cosmic ray energies might be accounted for by packing fractions was definitely incorrect. Nevertheless, experiments of this unambiguous kind have failed to clear up our still profound ignorance of the laws of nuclear absorption either for electrons or for photons. More experimental data are needed, a few bits of which have been recently supplied and are presented herewith.

In the low energy region—from 2 million up to 15 million electron-volts—the theory developed first by Oppenheimer and elaborated by Bethe and Heitler—a theory which simply adds to Klein-Nishina's extra-nuclear absorption a potent nuclear absorption due to the conversion of photons into electron-pairs by impact with a nucleus—this theory predicted quite well the experimental results found by Lauritsen and others on the absorption of photons varying in energy between the aforementioned limits in substances of different atomic number. The theory requires that the absorption in a given layer of matter be proportional to the energy of the incident photons and also requires it to vary as the square of the atomic number. Here, then, there seemed to be a real success and a promise that we had an approach to the laws of nuclear absorption for cosmic rays, for these same two laws apply also, according to the analysis of the foregoing authors, to the absorption of high energy rays consisting either of photons or of electrons. The first new result that I wish to comment upon looks like a still further extension of the Oppenheimer-Bethe-Heitler law of nuclear absorption into that cosmic-ray field.

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[1] *Proc. Nat. Acad. Sci.*, 12: 48–55, 1926.

[2] Chao, *Proc. Nat. Acad. Sci.*, 16: 431, 1930; *Phys. Rev.*, 36: 1519, 1930.

[3] See "Electrons (+ and −), Protons, Photons, Neutrons, and Cosmic Rays," pp. 321–330, for history of these measurements. University of Chicago Press, 1935.

Anderson and Neddermeyer last summer took 10,000 cloud chamber photographs on the summit of Pike's Peak, using our powerful magnet, built in 1931 expressly for measuring the energies of cosmic rays They have made laborious statistical studies of these photographs, and of a larger number taken at Pasadena, for the sake of directly measuring the loss of energy of electrons of various energies in traversing a plate of lead or of copper a few mm thick placed in the middle of the cloud chamber. These losses seem to check fairly well with the Oppenheimer-Bethe-Heitler theory in being roughly proportional to the energy of the incident electron up to 300 million electron-volts. They seem also to be proportional to the square of the atomic number. It was infeasible, however, to carry the measurements above the foregoing voltage. These experiments, again, seem to reveal the beginning of a real understanding of the nuclear absorption of cosmic rays.

But there are some well-established facts that speak against this theory, or that show that at least it is very incomplete. Here they are:

(1) Neher and Millikan have taken up in bombing planes, at March Field near Pasadena to altitudes of more than 20,000 feet, electroscopes shielded by as much as 15 cm of lead, and in other cases 15 cm of iron, and in still others 15 cm of aluminum. The absorption law followed by these shields approaches with increasing thickness *a first power law of atomic number rather than a second power law.* Similar experiments have been made at lower altitudes by Steinke and others in Germany with similar results.

(2) A second difficulty is that the total penetrating power of an electron of several billion electron-volts of energy is given by the above theory as less than three centimeters of lead, but in fact there is the best of evidence, both from electroscope readings and from counter experiments, that ionizing cosmic ray particles pass in straight lines through twenty or fifty or in extreme cases even a hundred cm of lead.

To save the theory, and yet avoid these difficulties it has been commonly assumed by some that these long-range particle tracks are not electron tracks at all, but are rather the tracks of heavy particles. For heavy particles, such as alpha rays or proton rays, are not known to produce x-rays or gamma-rays in targets into which they plunge, while both electrons and photons are well known to produce such secondary photons, electrons producing them (*bremsstrahlung*) with increasing copiousness and increasing efficiency as their energy increases. It is argued, therefore, that all the high penetration shown by cosmic rays may be attributed to heavy particles and that both such electronic and such photonic components of the cosmic rays as enter our atmosphere may indeed be absorbed in its very topmost layers, but that penetrating heavy particles in their nuclear collisions may produce electrons and that these electrons may then in their turn produce photons which quickly are changed into electron-pairs; so that all electrons and photons, however formed, may indeed be exceedingly rapidly absorbed as required by the electron-pair theory, while the heavy particles, though not themselves producing radiative collisions, may yet serve the purpose of carrying the cosmic-ray energy into the lower atmosphere and deep down into the great depths in water where it is actually found.

To discuss this theory it will be convenient to divide heavy particles into two groups—(1) protons and (2) all heavier nuclei. The latter category may be eliminated at once, for all nuclei except hydrogen are multiply charged, and since the ionization along a track is proportional to the square of the charge carried by the ionizing particle, the difference between a singly and a multiply charged particle-track could be at once observed in cloud-chamber experiments by the very great difference in the density of the tracks. But Anderson and Neddermeyer have studied more than 50,000 tracks and have observed an insignificant number that could possibly be produced by multiply charged particles coming in from outside, and the two or three that "might conceivably" have such an origin are adequately accounted for by their following recent discovery on Pike's Peak and at Pasadena.

This discovery is that there is a new kind of nuclear absorption that appears to bear no relation to the production of electron-pairs, an absorption in which the nucleus is definitely disintegrated with the ejection of a heavy ionizing particle, usually a proton, in addition to a number of either positive or negative electrons. These heavy tracks due to ejected protons reveal an energy which may rise to a hundred million volts, but unlike electron-shower tracks, which tend to move straight on in the direction of the incident ray, these proton tracks shoot backward about as often as forward, and in general are distributed *at random* about the center at which lies the disintegrating atom. Out of 10,000 track photographs taken on Pike's Peak about 100 such proton tracks, arising in most cases visibly and quite unambiguously from this kind of nuclear disintegration, are found; so that the two or three isolated heavy-track particles that "might conceivably" have come in from outside are with much greater likelihood attributable to such nuclear *disintegrations. This discovery shows, then, that the pair theory can not describe completely the observed facts of nuclear absorption.* There is as yet, then, no evidence at all for the penetration of heavily ionizing particles into our atmosphere so far as measurements up to the altitude of Pike's Peak are concerned.

But, also, measurements made by both Bowen, Millikan and Neher and by Regener up to very close to the top of the atmosphere fail to bring to light any evidence for an appreciable number of heavy ionizing particles. Bowen and Millikan pointed out as early as 1931[4] that when the pressure in an air electroscope is raised from say one to thirty atmospheres the fact that the factor by which the ionization at one atmosphere must be multiplied to get the observed current at 30 atmospheres is the same, whether these currents are produced by gamma-rays or by cosmic rays, means that the particles that do the ionizing as they shoot along their tracks through the electroscope must *on the average* be the same in the two cases. But in the case of gamma-rays they are known to be only electrons (+ and −). Therefore, in the case of cosmic rays, within the limits of discrimination of this experiment, they must be substantially all electrons. This holds up to such very high altitudes as those at which we have tested the agreement of air-filled electroscopes and argon-filled electroscopes. Similarly, the identity of Regener's depth-ionization curves, whether he uses an electroscope or a single ion counter as his detector, shows unmistakably, since the ion counter measures only "shots," while the electroscope measures ion-currents, that all the shots, whether they go through the electroscope or the counter, produce on the average the same number of ions per cm, otherwise the points on the electroscope curve would be consistently higher than the points on the ion-counter curve. A heavy particle would activate the ion counter just as would an electron, but it would make a bigger current in an electroscope.

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[4] *Nature*, **128: 583, 1931; also *Phys. Rev.*, 39: 397, 1932.**

These three types of experimental results then—(1) absence of heavy tracks, other than nuclear disintegration tracks in cloud-chambers, (2) identity of effects of gamma-rays and cosmic rays in pressure electroscopes filled with air, and (3) identity of electroscope altitude curves and single-counter altitude curves—constitute good evidence that heavily ionizing particles do not come into the atmosphere in appreciable numbers.

These arguments do not, however, apply to protons, since the ionizing track due to a proton and that due to an electron should be indistinguishable for energies higher than a billion electron-volts, so that whether protons come into the atmosphere or not must be determined by other types of experiments. The recently finished "Precision World Survey of Sea-Level Cosmic-Ray Intensities," by Millikan and Neher,[5] supplies, however, new and cogent evidence upon this point. This survey shows that from near the north magnetic pole (8° south of it) down to Pasadena (mag. lat. 41°) the sea-level intensity of cosmic rays does not vary by as much as 1 per cent. Its extraordinary constancy is best shown by the readings found on p 19, *Physical Review*, 50, 1935, representing five days of continuous readings night and day with two electroscopes in going from Victoria, B. C., to the latitude of Pasadena. A few miles south of Pasadena, however, it begins to decrease with extraordinary suddenness. This *single sudden setting in at magnetic latitude 41° of the "equatorial dip" provides excellent evidence that incoming electrons (+ and −), not protons nor indeed any other heavy particles, produce practically all the ionization at sea level that is due to incoming particles at all.* This evidence is found in the fact that *there is but one magnetic latitude, not two or three,* at which in going southward from the north magnetic pole this sudden setting in of the "equatorial effect" takes place. Its sharp setting in in latitude 41° enables the resistance of the atmosphere to incoming electrons to be fixed through the Epstein-LeMaitre-Vallarta analysis at about 6 billion electron-volts with a possible uncertainty of say 20 per cent. All the electrons of this energy that come into the earth at angles between 0° and say 45° to the vertical are just here, as one travels southward, being prevented from getting through the blocking effect of the earth's magnetic field. Hence the sudden diminution in sea-level intensity Electrons of slightly lower energy must get through the magnetic field at a little higher latitude, but *their* effect is not felt at sea level *because they have not enough energy to get through the resistance offered by the atmosphere.* This is all that can cause the flatness of the curve above latitude 41°.

Now, 6 billion volt protons are affected by the earth's magnetic field practically in the same way as are 6 billion volt electrons. If, then, protons penetrated the atmosphere more easily than electrons, because they do not make the radiative collisions which electrons make and which are in fact responsible for about half of the 6 billion electron-volts,[6] there would be a "proton shelf" in the sea-level intensity in about magnetic latitude 54°. That there is no trace of such a shelf can only mean that there are not enough protons coming in to affect the measured sea-level ionization. This means that so far as ionization measurements can determine, the whole ionization of the atmosphere that is due directly or indirectly to incoming charged particles is due to incoming *electrons*, not to incoming protons or other heavy nuclei

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[5] First published on December 13, 1935, in Carnegie Institution Reports No. 34; subsequently in *Phys. Rev.*, 50: 15, 1936.

[6] I. S. Bowen, R. A. Millikan and H. V. Neher, *Phys. Rev.*, 44: 246–252, 1933; also International Conference on Nuclear Physics, London, 1934.

We must find, then, other ways to circumvent the difficulties mentioned earlier. One other way is through the breakdown of the Oppenheimer-Bethe-Heitler law at high energies. That there must be such a breakdown follows from the following observations made by Bowen, Millikan and Neher in 1932.[7]

Their altitude-ionization curves taken in Peru (Mag. Lat. 3° S), Panama (20° N), March Field (41° N) near Pasadena, Spokane (54° N), and The Pas (63° N) showed no differences at all up to 22,000 feet, between Spokane and The Pas, but a notable difference (12 per cent.) between Spokane and March Field. The blocking effect of the earth's magnetic field begins in magnetic latitude 54° to cut out electrons of an energy of 2 4 billion electron-volts. The lack of any difference in cosmic-ray intensity between magnetic latitude 54° and magnetic latitude 63° and the notable drop of 12 per cent. in intensity between magnetic latitude 54° and magnetic latitude 41°, obviously mean that electrons of energy 2.4 billion electron-volts show a definite range or penetrating power, just as do electrons of an energy of 6 billion electron-volts, and also *that that range is less than half an atmosphere for 2.4 billion volt electrons, while it is a whole atmosphere for 6 billion volt electrons.* But this violates the Oppenheimer-Bethe-Heitler law, which requires the loss in energy of an electron going through any given thickness of matter to be proportional to the energy of the incident electron, and this means, in turn, that the coefficient of absorption, which is here practically inversely proportional to penetrating power or range, is the same for 2.4 billion volt electrons as for 6 billion volt electrons, while the experiment says unambiguously that the range of 2 4 billion volt electrons is less than half that of 6 billion volt electrons.

A similar failure of the Oppenheimer-Bethe-Heitler law seems to be indicated by the very recent stratosphere flights of Neher, Millikan and Haynes, who, on July 6, 7 and 8, sent up recording electroscopes to the highest altitude ever reached in cosmic-ray work. The accuracy of their readings, too, is far greater than that ever attained in sounding balloon work. In all preceding tests of this kind the observer has been obliged to get all his readings from one single discharge of his electroscope, although the rate of discharge at the top of the flight was as much as 200 times that at the start at sea level. These new Neher electroscopes were here automatically charged up anew every four minutes during a flight-period of 3½ hours from a light condenser which, after two years of development by Dr. Victor Neher and Dr. Sherwood Haynes, was so perfected that it lost less than ½ per cent. of its charge per hour—a really notable feat. This success made the accuracy just as good as that which we have ever obtained with heavy Neher instruments sent up in airplanes and charged every four minutes from 300-volt batteries—an accuracy from 30 to 50 times that obtained from electroscopes which make but one discharge in 3½ hours. The film shows that the photographic record of each discharge-rate is remarkably sharp and legible, also that the line which gives the barometric reading is very accurately readable. It was calibrated in the laboratory's vacuum chamber under essentially the conditions of the flight.

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[7] *Phys. Rev.*, 46: 641–652, 1934.

This line shows that *at the highest altitude reached the pressure was but 12.9 mm of mercury* or 17.5 cm of water, which is 98 3 per cent. of the way to the top of the atmosphere The electroscope record is also a perfect one at this extreme altitude This pressure, according to Humphrey's[8] tables, corresponds in summer to an altitude of more than 28 km or 92,000 feet. The ionization-pressure curve plotted from these readings is particularly interesting because it is the first record which shows the ionization of the upper air, as measured by an electroscope, *reaching a very definite maximum value,* in this case at 60 cm of water, or 4 4 cm of mercury, and then returning rapidly to lower values as still higher altitudes are reached. In this case the ionization at the highest altitude reached, where the barometer read 1 29 cm of Hg. is 22 per cent. lower than when the pressure was reading 4 40 cm of Hg Also, if this curve is compared with Regener's, which reached nearly the same altitude but was taken in magnetic latitude 50° instead of 38.5°, it will be seen that the lower energy electrons which can get through the earth's magnetic field at this higher latitude and which alone can make the difference between Regener's curve and ours, if they are both experimentally correct, do not penetrate nearly as far into the atmosphere before beginning to show that they have come into equilibrium with their secondaries, thus giving evidence again of the breakdown of the Oppenheimer-Bethe-Heitler absorption law. All this high altitude flight work, whether taken at extreme or at intermediate altitudes, seems to be in agreement with the "Precision Sea-Level Survey" in showing the absence of appreciable numbers of incoming protons and the breakdown at high energies of the nuclear absorption law based on the theory of pair-formation. We hope for further light on nuclear absorption phenomena from measurements like those just described now being made by Dr. Neher in the equatorial belt, near Madras, India.

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[8] Humphrey, "Physics of the Atmosphere," last edition, 1929.

UNCERTAIN INFERENCE

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AT a tercentenary celebration we shall do well to look both to the past and to the future In undertaking to address a mathematical audience, at the present time, on the subject of "Uncertain Inference" my chief care will naturally be to set forth, at least in outline, those very recent advances which have resolved effectively and conclusively the doubts, confusions and ambiguities which we can now see clouded the views and arrested the progress of those great predecessors to whom our subject owes its gradual development. But just as, behind the Harvard of to-day, the fully developed *alma mater* where future generations of Americans will train their minds and form their characters, we perceive the struggling ministers' training college of the seventeenth century, without which this other could not have been what it is; so we can only gain a just perspective of my present topic by recalling the steps, some hesitating, some even false, by which men have come gradually to understand how their reason may be applied to uncertainties, yet applied with logical rigor, and how, in particular, it may be applied to observational facts with all their limitations, their paucity in number and their imperfect precision, and yet draw from them precisely those inferences which the observations warrant.

The first great step was the development of the concept of mathematical probability. Much as this word has since been misapplied, to the writers of the seventeenth and eighteenth centuries its meaning was plain and unequivocal. For centuries, no doubt, *expectations* had been deemed capable of evaluation. Expectations under wills and expectations from uncompleted trading ventures had been bought and sold. In games of chance such expectations seemed capable of rigorous calculation. The structure of the game and its condition when broken off made it possible to assign to each player a calculable fraction of the amount at stake. This fraction, the ratio of the expectation to the prize which might be won, supplied the concept of probability. To Thomas Bayes, indeed, this was its definition.

The idea of probability seems to have been an essentially new one in mathematical thought. So far as we know it was unknown to the Greek and to the Islamic mathematicians. It was *sui generis* rather like the notion of temperature in physics, and it was novel particularly in this, that it brought uncertain consequences within the domain of exact or rigorous thought. If the apparatus used in gambling were true or unbiased and were fairly used, the probabilities of the game could be calculated with exactitude. From this point in time there was no excuse for mathematicians to confuse rigor with certainty. In the discussions on probability the uncertainty remained an integral part of the situation, but the concept of probability allowed the nature and extent of this uncertainty to be specified with rigor.

The possibilities of this situation were, of course, only slowly appreciated. Not till in our own days has it been realized that the fact that *some* uncertain inferences are rigorously expressible in terms of probability does not imply that the same concept is capable of providing an exact specification of the nature of uncertainty in *all* cases. We are now, indeed, familiar with logical situations of a different type which require to be specified in terms of mathematical likelihood; and there is, as yet, no assurance that even probability and likelihood together will suffice for the specification of every kind of logical uncertainty which may be profitably discussed.

For centuries, however, it was assumed that if uncertain inferences were to be made they must be made in terms of mathematical probability. It was, I believe, this assumption, more than any other factor which has led to efforts to define probability in more general, and usually in psychological, terms, and has introduced infinite confusion into the use of this once well-defined concept.

Thomas Bayes's paper[1] of 1763 was the first attempt known to us to rationalize the process of inductive reasoning. From time immemorial, of course, men had reasoned inductively; sometimes, no doubt, well, and sometimes badly, but the uncertainty of all such inferences from the particular to the general had seemed to cast a logical doubt on the whole process. By the middle of the eighteenth century, however, experimental science had taken its first strides, and all the learned world were conscious of the effort to enlarge knowledge by experiment or by carefully planned observation. To such an age the limitations of a purely deductive logic were intolerable. Yet it seemed that mathematicians would admit the cogency of deductive reasoning only. From an exact hypothesis, well defined in every detail, they were prepared to reason with precision as to its various particular consequences. But, faced with a finite, though representative, sample of observations, they could make no rigorous statements about the population from which the sample had been drawn.

Bayes perceived the fundamental importance of this problem and framed an axiom, which, if its truth were granted, would suffice to bring this large class of inductive inferences within the domain of the theory of probability; so that, after a sample had been observed, statements about the population could be made, uncertain inferences, indeed, but having the well-defined type of uncertainty characteristic of statements of probability. Bayes's technique in this feat is ingenious. His predecessors had supplied adequate methods, given a well-defined population, for stating the probability that any particular type of sample might result. His problem was, given a particular kind of sample, to state with what probability a particular type of population might have given rise to it. He imagines, in effect, that the possible types of population have themselves been drawn, as samples, from a super-population, and his axiom defines this super-population with exactitude. The problem thus becomes a purely deductive one to which familiar methods were applicable.

There is one point for which Bayes is seldom given enough credit. He had doubts as to the necessary truth of his axiom. So serious were these doubts that he withheld his entire treatise from publication until they should be resolved. It appears that they never were resolved; for his paper was published by his friends after his death.

That Bayes's essay was designed to meet a real need is shown by the eagerness and rapidity with which his work became the common property of European mathematicians. Laplace,[2] in particular, incorporated it into the foundations of his "Théorie analytique des Probabilités," cruelly twisting the definition of probability itself in order to accommodate the doubtful axiom It is certain that Laplace had no appreciation of Bayes's scientific caution. He says of Bayes, "Et il y est parvenu d'une manière fine et très ingénieuse, quoi qu'un peu embarrassée"

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[1] Thomas Bayes, "An Essay towards Solving a Problem in the Doctrine of Chances," *Phil. Trans.* 53: 370, 1763.

[2] Laplace, "Théorie analytique des Probabilités," 3rd Edition, Introduction cxlviii. 1820.

Substantial errors are so rare in the history of mathematics that mathematicians are remarkably unsuspicious of the work of their greater predecessors The illustrious authority of Laplace thus explains in some sort why Bayes's doctrine in its new dress was embodied without a query into the mathematical teaching of full two generations. To practical thinkers it seemed to meet a practical need To mathematicians it appeared robed in the authority and in the analytic elegance of Laplace's "Théorie" To De Morgan in 1835 it was still unquestioned gospel and one of the great steps forward in the history of his subject

The first serious criticism was developed by Boole[3] in his "Laws of Thought" in 1854 In that extraordinary work Boole anticipated many subsequent attempts to develop a symbolical logic, with particular reference to problems in probability He recognizes the contradictions and inherent arbitrariness of Bayes's axiom, as developed by Laplace, and quite properly treats it as an attempt to supply by hypothesis something which the data themselves lack

"These results only illustrate the fact, that when the defect of data is supplied by hypothesis, the solution will, in general, vary with the nature of the hypotheses assumed: so that the question still remains, only more definite in form, whether the principles of the theory of probabilities served to guide us in the election of such hypotheses. I have already expressed my conviction that they do not." . . . Bayes gives further reasons and adds: "Still, it is with diffidence that I express my dissent on these points from mathematicians generally, and more especially from one who, of English writers, has most fully entered into the spirit and the methods of Laplace; and I venture to hope that a question, second to none other in the theory of probabilities in importance, will receive the careful attention which it deserves"

Boole's criticism worked its effect only slowly In the latter half of the nineteenth century the theory of inverse probability was rejected more decisively by Venn and by Chrystal, but so retentive is the tradition of mathematical teaching that I may myself say that I learned it at school as an integral part of the subject, and for many years saw no reason to question its validity Mathematicians were averse from abandoning a theory, which often led to plausible conclusions, and, above all, which they had nothing to replace Its acceptance as orthodox effectively concealed from the majority the fact that, not a mere restatement in more accurate terms, but a fundamentally new approach, was required. As late as 1908 we find Edgeworth,[4] vague but definitely defensive: "I submit that very generally we are justified in assuming an equal distribution of *a priori* probabilities over that tract of the measurable with which we are here concerned."

Why should a mathematician defend a procedure for which he can say no more than that? And why should Karl Pearson, a few years later, put forward what he, and he alone, regarded as a *proof* of the disputed axiom. Such stubborn unwillingness to abandon a false position, to admit ignorance and to start again can only be due to mathematicians having so seldom experience of situations requiring an orderly retreat.

The need for an exact procedure of inductive inference was essentially a practical one, and the means for meeting it were being prepared by mathematicians having practical interests beyond those discussed by specialists in the academic theory of probability. Let us turn to Gauss and the foundations of the theory of estimation. As is well known, Gauss, at one time, developed his method of least squares by a formulation identical with that now used in the method of maximum likelihood, but which he justified as taking for the estimate the value of the unknown which had the highest probability. That would be, of course, the mode of its frequency distribution, if any such distribution could be assigned to it. Later, as he explained in a letter to Bessel, he let this argument fall into the background, through the conviction that maximizing the probability was less important than minimizing the injurious effects of the actual errors of estimation. To measure these injurious effects by the square of the error he regarded as arbitrary, though convenient.

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[3] Boole, "Laws of Thought," p. 375, 1854.

[4] F. Y. Edgeworth, *Journal of* the Royal Statistical Society, 71: 387, 1908.

Modern research has reconciled the two aims discussed by Gauss. If for any frequency distribution of a variable x

$$df = y(x)dx$$

where the frequency density y depends on some unknown parameter θ, the quantity

$$I = \int \frac{1}{y}\left(\frac{dy}{d\theta}\right)^2 d\chi_1$$

over all possible values of x, is invariant for transformations of x, and measures the amount of information which one observation x contains respecting θ. If x is itself an estimate of θ derived from a sample, the expression measures the intrinsic accuracy of an estimate having the sampling distribution given. For the particular and important case of the normal or Gaussian distribution the intrinsic accuracy is the invariance or the reciprocal of the mean square error Error curves of forms other than the Gaussian can thus be compared in their precision. When this is done it appears that the estimate obtained by maximizing the likelihood is in general the one for which the intrinsic accuracy is greatest.

A knowledge of the likelihood function thus takes the place of knowledge of a probability distribution in that type of uncertain inference with which the theory of estimation is concerned This logical situation is one of wide occurrence in the discussion of scientific theories of all kinds It presupposes a hypothesis containing one or more arbitrary parameters. The hypothesis is capable of specifying the probability or frequency of occurrence, of each of the observational facts which can be distinguished The probabilities of the observable occurrences are then functions of the parameters, and functions of known mathematical form. Only the values of the parameters are unknown. The theory of estimation discusses the advantages of the different methods by which these values can be estimated from an observational record Clearly there can be no operation properly termed estimation until the parameter to be estimated has been well defined, and this requires that the mathematical form of the distribution shall be given. Nevertheless, we need not close our eyes to the possibility that an even wider type of inductive argument may some day be developed, which shall discuss methods of assigning from the data the functional form of the population. At present it is only important to make clear that no such theory has been established.

The direct assessment of the amount of information supplied by a body of data, the sample of observations, and by a parallel and independent process of the amount of information extracted from the data, and contained in the estimate, brings to light the important fact that in some special, but specially important cases, these amounts are equal. The estimate exhausts the whole value of the data once the estimate has been calculated; the remaining facts which the data provide are entirely irrelevant to the value of the unknown parameter. Their distributions are, in fact, independent of the value of this parameter, so that we have the enlightening situation, of which the arithmetic mean of a normal sample, or of a sample from a Poisson series, are examples, in which, given the value of the first or sufficient estimate, the sampling distribution of any alternative estimate is independent of the quantity of which it is designed to indicate the value. All such alternative estimates are therefore worthless. The existence of sufficient statistics, in the sense defined above, is not only of theoretical interest as a possibility, but of great practical importance, for the cases in which they exist cover many of the forms most used by statisticians in practice.

Theoretically, however, the existence of sufficient statistics is exceptional, dependent as it is from a special functional relationship. When no sufficient statistic exists then no single estimate can contain the whole of the information supplied by the sample. There appears to be an inevitable loss, and in these cases the method of maximum likelihood is only preeminent in making this loss as small as is possible. The next task of the theory is to trace the cause of this loss and to discover in what way it may be made good.

Before turning to this fascinating inquiry, we must recall another development of modern mathematical statistics, in which again the practical requirements of research have moulded the mathematical structure. I refer to the establishment of exact tests of significance. These are now somewhat numerous and of many kinds, designed to cover the various cases which commonly arise in practice. They are all of quite recent origin, and I may take as typical the test of significance of the mean of a normal sample. This was published in 1908, which year, you may notice, is the same from which I have quoted Edgeworth's defence of inverse probability. Its author was a young man, then unknown, who chose to publish under the now celebrated pseudonym of "Student."

The classical procedure, dating at least from the time of Gauss, for testing the significance of the difference between the observed mean of a normal sample and zero, or any other value chosen for comparison, is to divide the difference by its standards error, as estimated from the sample. If $\bar{x}$ is the observed mean of n observations, and μ the true mean of the population from which the sample was drawn, then it has long been known that $\bar{x}$ is distributed in different samples in a normal distribution, with its center at μ and having a variance one 17th of that of the population sampled. If, therefore, we know the true standard deviation σ of this population, we should know that

$$\frac{(x-\mu)\sqrt{n}}{\sigma}$$

was distributed normally with unit variance, and so could assign with exactitude the probability with which any chosen value would be exceeded. In fact, the true value is not known, but we have in its place an entirely satisfactory estimate, x s defined by

$$S^2 = \frac{1}{n-1} S (x-\bar{x})^2,$$

where S stands for summation over the sample. This estimate is, in fact, a sufficient one, but it is none the less a fact that the value of s arrived at will usually differ more or less from the true value σ. Consequently, if we substitute s for σ, and calculate

$$t = \frac{(\bar{x}-\mu)\sqrt{n}}{s}$$

we are not justified in asserting that t will be distributed in the normal distribution. The originality of "Student's" approach lay in inquiring how in fact the ratio *t* is distributed, when calculated from samples of *n* observations. The exact solution is in fact given by the frequency element.

$$df = \frac{\frac{n-1}{2}!}{\overline{n-2}\,!\ \sqrt{\pi(n-1)}} \frac{dt}{\left(1+\frac{t^2}{n}\right)^{\frac{1}{2}n}}$$

a distribution very different in mathematical character from the Gaussian, though progressively approaching this form as *n* is indefinitely increased. The distribution is, however, exact and capable of tabulation for each size of sample possible. It has, in fact, at various times been rather thoroughly tabulated. Consequently, in place of asserting that there is a probability of one chance in forty that

$$\frac{(\bar{x}-\mu)\sqrt{n}}{\sigma} > 1$$

an assertion which would only be directly useful if it were known with exactitude, it is equally open to us, if, for example, our mean were based on fifteen observations, to assert that

$$t = \frac{(x-\mu)\sqrt{n}}{s}$$

has a probability of one in forty of exceeding the value 2.145. This statement is directly useful, for *s* is not unknown, but is calculable with exactitude from the observations.

Armed with this new tool, it was natural for practical experimenters to take a further logical step of great theoretical importance, namely, to use the ratio, *e.g.*, 2.145, appropriate to the level of significance chosen, to multiply this by the standard error of the mean *as estimated*, to add or subtract the product to or from the observed mean, and so to obtain working limits for the values of the unknown mean of the population.

In fact, since the distribution of *t* is known with exactitude, and since *t* is given by the formula

$$\frac{(\bar{x}-\mu)\sqrt{n}}{s},$$

which involves, apart from μ, directly calculable quantities only, namely $\bar{x}$ and *s*, both of which are sufficient statistics, we may infer, without any use of probabilities *a priori*, a frequency distribution for μ which shall correspond with the aggregate of all such statements as that made above, to the effect that the probability that μ is less than $\bar{x} - 2.145\,s/\sqrt{n}$ is exactly one in forty.

It is, at first sight, easy to confuse probability statements respecting unknown parameters derived by arguments similar to the above with statements of *inverse* probability. Indeed, attempts have been made to use these arguments by identifying the results to which they lead with statements of inverse probability, as a means of ascertaining which particular hypothesis of probabilities *a priori* should be adopted in order to lead to equivalent conclusions. In fact, the statements with which we are concerned differ materially in logical content from inverse probability statements, and it is to distinguish them from these that we speak of the distribution derived as a *fiducial* frequency distribution, and of the working limits, at any required level of significance, that may be derived from it as the *fiducial limits* at this level. This distinctive terminology is not intended to suggest that fiducial probability is not in the strictest sense a mathematical probability, like any other to which the term ought to be applied, but that it has been derived by a form of argument very different from that introduced by Bayes, and one which was unknown to all the early writers on the theory of probability.

It is a matter of some historical interest to examine why a mode of reasoning so essentially simple and so cogent as that outlined above should have escaped the penetration of the early writers, who include some of the most illustrious of mathematicians. There are two circumstances which may help to make clear this difficulty. The distributions studied by the early writers were nearly all discontinuous distributions, distributions in particular, of which the variates are frequencies. When applied to these the fiducial type of argument does not lead us to an exact frequency distribution of the unknown parameters, but only to a series of inequalities which add little in intelligibility to the tests of significance from which they may be derived The neglect of the frequency distributions of continuous variates, until they were forced on the notice of mathematicians by the requirements of the quantitative sciences, is, I believe, one potent reason why early writers on probability were not led to use arguments of the fiducial type For such arguments to be fruitful, moreover, the distributions considered must be not only continuous, but mathematically exact Exact solutions of all the more important and immediate problems were possible by analytic methods certainly within the capacity of the greater writers of the last 150 years. That their existence remained for so long unknown can only, I believe, be explained by the absence of any steady conviction that inferences involving an element of uncertainty *deserve* anything better than rough and approximate discussion.

Two subsidiary circumstances, also, have in our own time greatly facilitated the new approach. One is the convenient practice of tabulating the distributions required at a series of definite levels of significance, *i.e.*, of expressing the variate in terms of the probability, in place of regarding the probability as a function of the variate The second circumstance is the abandonment of the inverse type of argument, since so long as statements of inverse probability were held to be the aim, the possibility of making inferences of fiducial probability, which differs from the former in logical content, was very naturally overlooked.

There is one peculiarity of uncertain inference which often presents a difficulty to mathematicians trained only in the technique of rigorous deductive argument, namely, that our conclusions are arbitrary, and therefore invalid, unless all the data, exhaustively, are taken into account In rigorous deductive reasoning we may make any selection from the data, and any certain conclusions which may be deduced from this selection will be valid, whatever additional data we may have at our disposal. The more philosophic writers on probability, however, such as Venn, have emphasized the fact that conclusions in this field are relative, not only to what is known, but also to what is undetermined Venn, for example, contrasts the conclusions to be drawn from such items of information as that the death-rate of Englishmen is higher in Madeira than in England, and that the death-rate of tuberculous patients is higher in England than in Madeira The probable effect of a change of residence is difficult for the contrasted cases of a man chosen at random from the English population, as against one chosen at random from the tuberculous patients of that country. The additional datum that the individual chosen is tuberculous must not be ignored in drawing inferences from the remaining data.

This peculiarity appears to be characteristic of uncertain inference in general. It is certainly as important in inductive reasoning from observational data as in the purely deductive inferences of the classical theory of probability. Every statistician is conscious that if he were to allow himself to make an arbitrary selection among the observational material available, then the most orthodox operations of his craft could be made to lead to almost any desired conclusion. The political principle that "Anything can be proved by statistics" thus enshrines a subtle truth, which requires to be the more carefully borne in mind, the more we rely on mathematical techniques developed with only *certain* inferences in view

This consideration is vital to the fiducial type of argument, which purports to infer exact statements of the probabilities that unknown hypothetical quantities, or that future observations, shall lie within assigned limits, on the basis of a body of observational experience No such process could be justified unless the relevant information latent in this experience is exhaustively mobilized and incorporated in our inference

We may now appreciate the necessity of the condition I mentioned, in connection with "Student's" test of significance for the mean of a normal sample; namely, that the quantities x and s, which, together with the unknown parameter μ appear in the expression for t, should be sufficient estimates of the mean and standard deviation of the population sampled For this is a guarantee that they have together tapped all the information the sample has to give respecting the nature of the population If alternative estimates had been used; if, for example, we had found the median in place of the arithmetic mean, or, if we had used Peter's formula, based on the mean deviation, in place of Bessel's formula, based on the mean square, we might have derived an entirely valid test of significance; that is to say, we could have found a quantity, t', with a distribution exactly known for samples of a given size, and expressible, like t, in terms of the unknown parameter, together with directly calculable quantities only. But, if we had gone further, and, substituting for t', in terms of μ, had derived a fiducial distribution of the unknown parameter, the distribution we should obtain would be based only on that part of the information available which our special estimates of the mean and standard deviation had conserved. The distribution obtained would differ from that found by using the sufficient estimates, and the probability statements which it embodies would be discrepant. Without the requirement that the information available should be exhausted, a host of discrepant inferences would appear equally admissible, each dependent from the particular choice of the statistician, through his choice of the method of estimation to be employed

When sufficient estimation is possible, there is here no problem, but the exhaustive treatment of the cases in which no sufficient estimate exists is now seen to be an urgent requirement. This is at present in the interesting stage of being possible sometimes, though, so far as we know, not always I have spoken of the sufficient estimates as containing in themselves the whole of the information provided by the data. This is not strictly accurate There is always one piece of ancillary information which we require, in addition to even a sufficient estimate, before this can be utilized. That piece of information is the size of the sample, or, in general, the extent of the observational record; and we always need to know this in order to know how reliable our estimate is. Instead of taking the size of the sample for granted, and saying that the peculiarity of the cases where sufficient estimation is possible lies in the fact that the estimate then contains all the further information required, we might equally well have inverted our statement; and, taking the estimate of maximum likelihood for granted, have said that the peculiarity of these cases was that, in addition, nothing more than the size of the sample was needed for its complete interpretation. This reversed aspect of the problem is the more fruitful of the two, once we have satisfied ourselves that, when information is lost, this loss is minimized by using the estimate of maximum likelihood. The cases in which sufficient estimation is impossible are those in which, in utilizing this estimate, other ancillary information is required from the sample, beyond the mere number of observations which compose it. The function which this ancillary information is required to perform is to distinguish, among samples of the same size, those from which more or less accurate estimates can be made, or, in general, estimates having different frequency distributions.

The most general procedure of this kind possible would be, from a sample of *n* observations, to specify (a) the estimate, or set of estimates of the unknown parameters, having the greatest possible likelihood; and (b) a set of functionally independent ancillary statistics, sufficient in conjunction with (a) to allow the observations to be reconstructed in their entirety, and having the additional property that these ancillary quantities shall be all distributed in samples in distributions independent of the unknown parameters. It is easy to see that this can be done in certain simple cases. For example if μ is the only unknown parameter in a frequency distribution specified by the differential element $df = \phi(x - \mu)dx$, then the difference between successive observations, when arranged in order of magnitude, supply $n-1$ functionally independent quantities, calculable from the sample, the sampling distribution of each of which is evidently independent of μ. We may, therefore, regard such a set of differences as specifying the configuration of the sample, and, in interpreting our estimate, may take as its sampling distribution that appropriate to only those samples which have the actual configuration observed.

Here, then, is a second group of solutions, by which estimation may be made exhaustive, like the sufficient statistics in depending from a special functional relationship, like them, also, in resolving a wide class of the problems arising in practice. And my final word on this topic is a query, the answer to which so far is unknown, and which is, therefore, at present a challenge to our mathematical intuition. May I put the problem in this form:

> The agricultural land of a pre-dynastic Egyptian village is of unequal fertility. Given the height to which the Nile will rise, the fertility of every portion of it is known with exactitude, but the height of the flood affects different parts of the territory unequally. It is required to divide the area, between the several households of the village, so that the yields of the lots assigned to each shall be in predetermined proportions; whatever may be the height to which the river rises.

If this problem is capable of a general solution, then it is possible in general to recognize something corresponding with the configuration of the sample in the simple case discussed above, and one of the primary problems of uncertain inference will have reached its complete solution. If not, there must remain some further puzzles to unravel.

HORMONES

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All who are familiar with the proved facts of endocrinology will, I think, unhesitatingly agree that the hormones, those chemical messengers produced by that specialized group of tissues known as the ductless glands or glands of internal secretion, play an essential rôle in the maintenance of normal bodily functions, both physical and mental, in the human individual. Hoskins[1] has said: "The evidence is now conclusive that what we are—physically, mentally, sexually and emotionally—depends in no small measure upon the functions of the endocrine glands. They cooperate in an important way in the regulation of our activities in health and modify the course when they do not primarily determine our diseases." I think that the significance of the internal secretions in relation to human behavior can be realized best if they are considered from the standpoint of their biological value Any living animal organism, whether it be man, at the top of the evolutionary scale, or the jelly-fish, near the bottom, or any other of the various living things which are intermediary between these two, must be considered from the biochemical view-point as a machine. From time immemorial, from the dawn of life on the globe, environmental factors, together with the inherent properties of protoplasm, have contributed to a constant change in the types of living things. All these have been more or less efficient machines, and of those types which have survived it may be said that they were adapted to their environment. There are two basic types of mechanism which are possessed by members of the animal kingdom, each of which plays a specific part in the regulation of the various functions and activities of the organism as a whole. These are the nervous system and the chain of endocrine glands. Professor Adrian has dealt already with the former. In the lower forms of animals, the great group invertebrata, the nervous system is probably preeminent; in fact, very little is known of the hormones or their functions in the invertebrates. The situation, however, in the vertebrate kingdom is quite different. Here, from fish to mammal without exception, we find the ductless glands represented in all forms and integrating with the nervous system in the control of the animal machine of which they form a part.

While there are vast differences between animals of different phyla and smaller but important differences between different species, there is as yet no reason to doubt, in so far as the hormones are concerned, that the active principle elaborated by a ductless gland in the fish does not differ materially from that elaborated by the same gland in man or other mammals. An excellent example of this is to be found in the case of insulin. An extract prepared from the principal islets of teleostian fishes or from the pancreas of the elasmobranch manifests the same physiological properties when tested upon a normal rabbit or a diabetic patient as does the insulin prepared from the pancreatic glands of cattle, pigs or sheep. There may be quantitative differences relative to the effects of individual hormones of different animal origin, but qualitatively they give the same physiological effects in adequate test objects.

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[1] R. G. Hoskins, "The Tides of Life." W. W. Norton and Company, New York, 1933.

But though the hormone may be the same from fish to man, its function in fish and man may conceivably be different. As Thomson[2] has pointed out in a discussion on the evolution of hormones, there are, on the one hand, cells which elaborate the specific chemical substance and, on the other, cells which respond to the presence of this substance once it is brought to them. There are examples of the apparently useless presence in relatively primitive organisms of chemical substances which in higher groups have acquired a physiological function as hormones. It may be, of course, that the significance of such substances as oestrin in insects, of adrenalin in annelids, of the oxytoxic posterior pituitary principle in fishes, is yet to be discovered, and that it may ultimately be established that all these have a true hormone function in every form in which they are found. The point raised by Thomson of the lack of a complete parallelism in the phylogenetic development of hormones and in their functional manifestations is worthy of much further study.

A good example of the fact that the same hormone may act upon different types of tissue in different species is illustrated in the case of prolactin of Riddle. This anterior pituitary lobe principle stimulates the fully developed mammary gland of the guinea pig to milk secretion, and in the pigeon it causes the growth of a structure known as the crop gland, the development of which is essential for the production of crop milk. The underlying physiological effect is in each case the same, but the structures acted upon very different. These two analogous organs must have developed separately their responsiveness to this anterior pituitary principle.

When an endocrine linkage is evolved, it probably represents a delegation of authority formerly resident elsewhere. As an example of this, sexual dimorphism of plumage in the sparrow is apparently controlled by the chromosomes of the individual epidermal cells, whereas in the fowl this control has been turned over to the presence or absence of the ovarian hormone. Again testicular hormone is essential for the growth of antlers in the red deer but not in closely related reindeer. These examples may serve to show that the delegated authority may easily be reassumed with but a small change in the genetic constitution. Failure to realize this has led to some of the wildest and least plausible speculations ever associated with any branch of science. It seems, for example, nothing short of fantastic to argue that because in white races destructive disease of the adrenal glands may tend to pigmentation of the skin, therefore the black races display under-development of this gland—forgetting that this should also condemn them to extreme muscle debility, infertility, etc., etc. It seems, too, that similar pitfalls must await all those who argue that because many of the sufferers from some particular endocrine disorder have a characteristic gait or complexion or expression, all those who at first glance resemble them are necessarily sufferers from the same fundamental disorder.

Apart from exceptions of the type indicated above, it is the general rule that the function subserved by any particular hormone is much the same in all the higher animals. I desire to emphasize this now especially because in any discussion as to the relationship of hormones to human behavior it is very easy to overlook basic principles, and in so doing to be led astray. Many such discussions in which due regard has not been had for fundamental ideas have unfortunately found their way into print. I fear that such writings are more apt to hinder than to accelerate progress in the application of the known facts of endocrinology towards the solution of problems on factors relating to human behavior

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[2] D. L. Thomson, *Nature*, 80: 543, 1932.

I should like now to direct my discussion from the animal kingdom in general to man in particular. It may be said of the individual man that his own peculiar character and physical make-up are the outcome of the phylogeny of his species and are the resultant of the special forces to which his progenitors have been subjected in the course of countless generations. While man as a living machine differs in no essential manner from the higher animals, he has a brain the frontal lobes of which have been developed to an extent not seen in other forms, even in the anthropoid apes The evolution of modern man as a social being differing in so many respects from other species has of course been attributed to the specialized development which has taken place in this particular part of the brain. He is endowed not only with consciousness but with self-consciousness. Entirely apart from the basic importance of this latter to psychology, it is of great significance from the biological aspect Man by virtue of his self-consciousness can think and in thinking can will, and in so doing he can modify in a most profound manner various bodily functions which are amenable to modification by nervous stimuli. In other words, the great development of the cerebral cortex in man has allowed of the opening up of new channels of nerve communications. The outgoing pathways from the central nervous system to the ductless glands are probably developed to much the same degree in the lower forms as they are in man; but in the latter, due to the further development of the brain, impulses can arise in higher centers which can motivate peripheral structures by way of the older pathways. As far as we know, practically all the tissues and organs of the body are in direct connection with the central nervous system. The various ductless glands are no exception to this rule, and while much yet remains to be done in connection with the nervous control of these structures, it is safe to assume that all the endocrine organs are directly or indirectly under nervous control. The extent to which, on the other hand, the nervous system itself is dependent upon or affected by individual endocrine gland secretions must be for the most part a matter of conjecture at this time In connection with these two great systems, the nervous and the endocrine, we must recognize an integrative action not only in regard to their effects upon other structures but in their effects upon one another So while it is true that man as a biological machine is similar to the animal, he has these two systems—the nervous and the endocrine—which may function on a higher level.

The behavior of the individual man is in part the expression of his conscious, self-conscious and unconscious life. It becomes obvious, therefore, that the endocrine glands, which, with the nervous system, have so much to do in the regulation of the various bodily functions, must in an indirect way influence profoundly his behavior.

Let us consider the hypothetical case of the normal man with normal behavior. The endocrine system of such an individual may be considered simply as a part (a very essential and important part) of this human machine It functions continuously, now faster, now slower, in its various parts—all the while responding to stimuli both nervous and chemical, and liberating from its various components now more, now less of the individual internal secretions which play their rôle in the regulation of the various bodily functions. It may be said, because each of the various hormones contributes a definite part to the maintenance of the normal state of the body of this hypothetical individual, that each therefore has a definite effect upon his behavior. In dealing with a normal body and normal behavior, the relationship of hormones to the behavior pattern is not at once apparent, and the point of view just expressed might be thought by some to be unjustifiable. The evidence that certain types of abnormal behavior patterns are due to disturbances in the endocrine system is very convincing; also there are many examples of the behavior pattern being modified by too much or too little of some hormone. It would therefore seem logical to conclude that the normal behavior manifested by our hypothetical normal man is as much dependent upon hormones as certain alterations in the behavior pattern are dependent upon alterations in the hormone balance.

There is a variety of well-established experimental as well as clinical results which demonstrate quite conclusively that the behavior of individuals may be altered owing to the presence of too little or too much of some hormone agent in the circulation. Such effects of hormones are usually indirect rather than direct. Some illustrations of this follow.

THYROID

Thyroid disease is fairly common, and patients suffering from this type of disability may show evidences of over-stimulation by the thyroid hormone or they may manifest the signs of thyroid hormone deficiency. All sorts and varieties of intermediate stages are of course met with clinically. The behavior patterns of the two types are diametrically opposed and each deviates far from normal. Barker has described these two types of thyroid disease as follows. The hyperthyroid type, as seen in the case of exophthalmic goiter, is hypersensitive to mental stimuli, is irritable and restless. Patients suffering from this malady often exhibit characteristic anomalies; sometimes they suffer from pathological fears, obsessions or ideas of injury; occasionally they show marked excitement not unlike that seen in hypomanic states. In myxoedema, on the other hand, in which there is under-function of the thyroid gland, the patients present a strikingly different mental state and behavior. The facial expression is apathetic and quiet; the patients seem drowsy and dull; their thoughts come slowly and their emotional reactions are sluggish Barker[8] emphasizes, however, that though there are profound changes in thinking, feeling and striving in thyroid disease, it is relatively rare that outspoken psychoses occur either with frank over-function or under-function of the thyroid. When they do appear, he states, these psychoses appear to have their origin in an associated psychopathic inheritance rather than in endocrine anomalies alone.

PARATHYROID

One of the chief functions of the parathyroid glands is to regulate the level of calcium in the blood stream. The maintenance of normal tone in muscle and nerve is among other things dependent upon ionic concentration of calcium and other inorganic elements. A lowering of the calcium ion concentration disturbs this balance, and a hyper-excitable state of the nervous system is the main effect of such a change. There is a hyper-excitability of the entire nervous system in hypoparathyroidism, of which the resulting manifestation may be tetany. The opposite condition, a profound loss of muscle tonus, is occasionally met with in chronic cases. I recall one case in particular (which I saw some years ago) in which this condition of atonia was the predominant symptom. This patient was for a time considered to be a mental case. He could be roused from a stuporous state only with difficulty and his speech was incoherent. When it was found that his blood serum calcium was only half the normal value, appropriate treatment was instituted and his rapid return to normal both mentally and physically was truly remarkable.

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[8] L. F. Barker, Florida Med. Assoc., 1927, 1.

GONADS

Some of the most outstanding examples of the effects of hormones on behavior are to be found in the field of sex physiology. Moreover, the remarkable researches that have been made of late by chemists working in this field have made available synthetic products which have the same physiological properties as the male and female hormones ordinarily found.

The general characteristics of "maleness" and "femaleness" are undoubtedly due to the action in the organism of the male hormone and the female hormone, respectively. Also, there seems little doubt that the fluctuating concentration of sex hormones in the blood of woman is the basis for a number of altered behavior patterns so peculiar to the female. It may be confidently expected that great advances will be made in this subject in the near future, because accurate methods for the assay of certain of the hormones in the blood and secretions of the individual are being developed.

SUPRARENAL GLANDS

Although the suprarenal glands in man and the higher vertebrates appear on macroscopic examination to be a pair of discrete structures, actually they consist of two distinct types of tissue, one of which, the medulla, is developed in close association with the sympathetic nervous system; the other, the cortex, is more closely related to the genital organs in its development. Two definite and distinct hormones have been obtained from suprarenal tissue—adrenin and cortin—and there still remains the possibility that other active principles may be obtained from these very important endocrine glands. The symptoms which develop in patients with suprarenal gland disease depend upon which part is involved Thus, there may be evidences of under- or over-activity of medulla or cortex or of both medulla and cortex. A discussion of the various types of suprarenal cases and their behavior characteristics would take us too far afield. Suffice it to say, since one suprarenal hormone (adrenin) is a sensitizer of the sympathetic nervous system, and abnormal functioning of the cortex may result in profound changes in the secondary characteristics of sex, that there is here a hormonal background for each of a variety of behavior patterns manifested by those suffering from suprarenal disease.

PANCREAS

The hormone insulin produced by the islet tissues of the pancreas furnishes an excellent illustration of an indirect effect of an endocrine secretion upon behavior. In severe untreated cases of diabetes the blood sugar level is elevated and there is a condition of acidosis due to the presence in the blood stream of large amounts of the so-called acetone bodies. By the proper use of insulin the blood chemistry of these patients may be restored to normal and with this restoration of certain of the blood constituents to normal values there is as a rule a great change in the mental attitude and outlook. If, however, an overdose of insulin is given, or if adequate carbohydrate is not available, the blood sugar may fall below normal and, if this condition of hypoglycemia is allowed to progress, a convulsive seizure with loss of consciousness may result. During the time that the blood sugar is falling from the normal level to the convulsive level, various changes may occur in the patient's subjective sensations. There may be at first a sensation of hunger, to be quickly followed by faintness. The subject may gradually become inarticulate, although still quite conscious, but consciousness is soon lost and a convulsive seizure occurs. This, if untreated, may end fatally. A small quantity of sugar will in a few minutes restore a patient in hypoglycemic shock to normal

The hormone adrenin raises the blood sugar by virtue of its ability to cause glycogen, which is present in the liver and muscles, to break down to glucose. Professor Walter Cannon and his colleagues[4] in their brilliant presentation have shown that the suprarenal glands may be activated in a number of ways to discharge adrenin; chief among these were pain, hunger, fear and rage. A good example of this emergent function of the suprarenals was recently reported to me I would like to quote it because it furnishes an excellent illustration of the effects of two hormones in the same subject

A diabetic patient taking the insulin treatment realized one morning as he was walking down the street that he was developing a hypoglycemic reaction. Finding that he had forgotten to provide himself with a chocolate bar, he proceeded to the nearest drug store. By the time he reached the store his gait was unsteady and his speech incoherent. He tried to explain to the druggist what he wanted, but the latter, fully convinced that he was dealing with a drunken man, threw him into the street. The patient, still conscious and terribly enraged at being so treated, promptly recovered and proceeded to another store unaided, made his wants known and continued on his way. Obviously we have here an example of the activation of the adrenals as a result of anger, leading to the release of enough adrenin to cause an increase in the patient's blood sugar sufficient to restore his equilibrium and his powers of speech.

The Anterior Pituitary Lobe

Research work of the past few years in connection with anterior lobe physiology has established this organ as a master-gland among the endocrines. This is due to the fact that it exercises a trophic influence on a number of these, such as the thyroid, the suprarenal and the gonads. Over-activity or under-activity of the anterior pituitary is therefore bound to result in changes in other glands. These will be over-stimulated or under-stimulated according as the anterior lobe is liberating more or less of the specific trophic principles In cases of manifest disordered functioning of any of the pituitary-controlled ductless glands, the question always arises as to whether the particular gland in question is on an abnormal functional level due to a change in anterior lobe activity or whether the abnormal condition is due to a primary change in the gland or glands involved.

Because of this close functional association between the anterior pituitary and other glands of internal secretion, it is possible that most of a group of widely divergent cases of obvious endocrine disease may have one thing in common—namely, a primary functional disturbance in the anterior lobe. Clinicians will agree, I think, that most frank endocrine cases have abnormal behavior patterns, and since the dominance of the anterior lobe in the endocrine chain is established, it would appear that this gland and its various hormone products have more to do with behavior in the human subject than any other gland or glandular secretion.

While the variety of cases possessing altered anterior lobe function is great, two types are often referred to, to illustrate on the one hand the results of over-activity and on the other under-activity of this gland. The former is acromegaly and the latter pituitary dwarfism. In the early stages of acromegaly there may be obvious signs of hypergonadism and hyperthyroidism. Barker[5] states that marked mental disturbances, frequently of a hypomanic character, may be associated with this form of hyperpituitarism. Most of these cases tend to show signs of failing pituitary function in later years, often accompanied by corresponding changes in mentality. Atkinson, writing on acromegaly, cites fifty-four authors who in their publications on this disease mention personality changes of varying severity from simple melancholia to manic depressive insanity and schizophrenia. As early as 1897, Brunet stated that one quarter of all cases on record within ten years of the first case described by Pierre-Marie showed personality changes. Cushing[6] found that in one form or another psychic irregularities were manifested in the larger number of patients suffering from this endocrine disease.

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[4] W. B. Cannon, "Bodily Changes in Pain, Hunger, Fear and Rage." Appleton and Company, New York, 1916.

As a result of a critical investigation of many endocrine cases, the late Allan Winter Rowe[7] concluded that frank psychoses and less well-defined psychoneuroses find a definite representation in all the groups of endocrine disorder. He found that the prepubertal pituitary case was frequently a child with a behavior problem. He found that cases of pituitary disease manifesting the Frohlich syndrome usually had a genuine lowered mental acuity. The adult pituitary cases studied by Rowe showed a definitely high percentage of individuals mentally normal. Those who tended toward hyperfunction frequently showed high intellectual capacity.

The pituitary dwarf is as a rule, in the early years at least, within normal limits in so far as behavior is concerned. As the subject grows older, however, there may develop an abnormal behavior pattern as an indirect result of the hypopituitarism. The short stature and the hypogonadism are the usual causes of the changed mental outlook which some of the older cases present.

A good example of marked behavior change in the dog, which can be attributed to hormone treatment, is afforded by the young animal that has been hypophysectomized and then after several weeks is treated with a potent hypophyseal extract. Cushing,[8] in his pioneer work on the pituitary gland, described many examples of behavior and personality changes which he had observed in his hypophysectomized dogs. The case of a wolf-hound puppy studied recently in my own laboratory is of particular interest in this connection. It was observed, soon after the removal of the pituitary gland, that the animal, although belonging to a naturally aggressive stock, became extremely stupid and timid in his behavior. There was, in fact, a clear-cut deterioration in his behavior from the normal pattern of the wolf-hound puppy. After many months the animal was treated daily with an anterior pituitary extract. Within a few days the animal's general behavior and personality were markedly altered, so that he acted much more like the normal type. The change was so apparent that a worker in the laboratory, unaware that treatment had been started, commented upon the unusual activity of the animal and asked if anything had been done which might account for it.

Cases such as this, proving as they do that the level of intelligence in an animal can be raised as a result of the action of certain hormones, afford a background which should allow us to look forward with a greater degree of confidence to the possibility of applying the results of endocrine research to the solution of some of the problems of human behavior.

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[5] *Loc. cit.*

[6] H. Cushing, "The Pituitary Body and Its Disorders." J. B. Lippincott, Philadelphia, 1912.

[7] A. W. Rowe, Collected papers from the Evans Memorial Hospital.

[8] *Loc. cit.*

In the discussion thus far I have attempted to show that the endocrine system and its products, the hormones, constitute an essential part of the animal machine; since individual human behavior must of necessity be dependent upon the nature of the body which the subject possesses, it follows that hormones, one of the variable quantities in that body, can contribute both directly and indirectly to the particular pattern manifested at any one time. Let us now examine a little more closely into the mechanism by which hormones can influence human behavior. As a starting point, I can not do better than to recall to you some of the principles of genetics which are applicable here. Since the development of each individual follows from the original union of two cells, the sex elements egg and sperm, it follows—whatever the outcome may be—that it has been predetermined in large measure by the character of these two cells. The fact that this predetermination is due to the chromosomes of the parent cells and the countless genes which they contain has long since been established by the research work of the geneticists Some of the properties of the genes, the agents directly responsible for the transmission of hereditary characters, are worthy of note here, because of the important bearing which they have on the subject under discussion. They are able to reproduce themselves exactly; they are in a way independent of one another and each gene may have a separate or independent effect upon development; one gene may produce effects in more than one organ, and many different genes may affect a single organ. It has been stated, for example, that the eye of the fruit-fly may be affected by more than fifty different genes.[9]

Riddle[10] has said: "Our stature, our facial features, the color of our eyes, skin and hair, the capacity of our blood to clot, our susceptibility to certain diseases and certain malformations of our bones and the nervous system, are all known to be influenced by genes. On the mental side, color blindness, feeblemindedness, some gradations of mental ability, and some forms of insanity are known to be influenced by genes." An interesting example of a type of idiocy with which there is an associated metabolic disturbance (the excretion of phenyl-pyruvic acid) has been studied by Penrose[11] and ascribed by him to a single recessive gene.

Some sixteen years ago, Riddle started an experiment to establish races of pigeons characterized by increased or decreased function of some of their endocrine glands. He started with twenty-four pairs of birds taken from mongrel stock and bred them for fifteen generations, all the while selecting only individuals with particular types of glands for inbreeding. His most outstanding results were obtained in connection with the thyroid gland. He was able to produce three distinct strains or races, the individuals of each of which had a constant thyroid size, but the thyroid size was different in each of these races. But more important still, Riddle was able to show that the birds of different "endocrine" strain differed markedly in their basal metabolic rate, in body size and in their degree of response to certain hormones injected into them. As Riddle remarks: "How much more valuable would such an experiment have been if it could have been done on human beings, because differences in behavior and in mentality could have been recorded." In any case, this most valuable contribution of Riddle shows unmistakably the great importance of genetic factors in relation to the development of the endocrine glands of each individual. Behavior, then, of the individual in so far as it is influenced by the endocrine glands is indirectly dependent upon the genes to which he has fallen heir and which, together with environmental forces, determine his endocrine constitution. This brings us to the constitutional factor which is so important in dealing with almost all human ailments, mental or physical. This is simply the expression of the combined results of the action of environmental influences and hereditary factors which have through their agents, the genes, made the individual what he is

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[9] H. S. Jennings, "The Biological Basis of Human Nature." W. W. Norton and Company, New York, 1930.

[10] O. Riddle, Unpublished lecture, Cincinnati, 1936. Quoted by kind permission of the author.

[11] L. S. Penrose, *Lancet*, 1: 23, 1935.

The studies of Smith and MacDowell[12] on the dwarf mouse furnish another excellent illustration of the effect of genetic factors on endocrine gland development. These authors have shown that a single gene controls the development of certain cells in the pituitary gland, and it is probable, when this gene is not present in the chromosomes of the mouse, that its pituitary gland can not secrete certain of the active principles which the normal gland produces and liberates.

Environment is another important factor affecting endocrine activity. The hormones circulating in the blood constitute a part of the internal environment of living things. As pointed out earlier, the activity of the endocrine glands themselves may be affected by environmental factors and here the nervous system is often the channel used in communicating the stimulus arising in the external environment to the cells which produce the hormones. Blood-borne messages by means of chemical agents may also play a part here.

It is well recognized that environment can affect profoundly both physical and mental development, and hence behavior. Mendel was able to produce much larger rats by means of special diets; and, to borrow an analogy from the plant world, the growing soy-bean under red-yellow light will become a delicate twining vine; under blue-violet light it becomes a sturdy herb.[13] There are in the case of the human family cases of whole peoples showing behavior which we should judge as definitely abnormal, in whom as yet no evidence of physiological abnormality, endocrine or otherwise, has been described Examples such as paranoia in Dobu and the megalomania of the Kwakiutl must certainly be due in the main to the special environmental influences prevailing in each case—namely, the specific culture-patterns evolved by these societies Yet, even in such societies as these, as in our own, there are doubtless differences of temperament and individuals who depart from the norm of the society in one direction or another; and it may well be that endocrine factors partly determine such individual variations. It may also be noted in this connection that even if the contention of the psychoanalysts be accepted, behavior traits in adult life are largely determined by the infant's solutions to the problems by which it is confronted—especially problems of nutrition, excretion and sexual relationships—nevertheless, there is room in such theories for genetic factors, in part possibly endocrine, which in their turn determine which of the various possible solutions of these problems the child may finally accept.

While modern endocrinology was yet in the embryonic stage of development, the great French physiologist Claude

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[12] P. E. Smith and E. C. MacDowell, *Anat. Record*, 46: 249, 1930.

[13] W. H. Popp, *Contrib. Boyce Thompson Institute for Plant Research*, 1: 241, 1926.

Bernard pointed out that in all animals with complex organization the living parts exist in the fluid which bathes them. He called this the "milieu interne," the internal environment. Bernard recognized the great importance of the fixity of this internal environment as a condition for free and independent life. As Cannon has said, "The fluid matrix of the body is made and controlled by the organism itself." It is this ability of the higher forms of animal life to preserve uniform the composition of their tissue fluid that makes them more independent than their lowly ancestors of changes in the external environment. Many varied and complex physiological reactions together maintain the steady state of the internal environment. Such steady states which result from the coordination of various physiological processes have been described by Cannon as "physiological homeostasis." But in spite of the efficiency of the organization for homeostasis, changes of sufficient degree do occur at times in the internal environment to cause profound repercussions. Removal of an endocrine gland, for example, has an immediate effect on the internal environment, and in the period which follows, during which adjustment to the altered state is taking place, changes in many other organs may take place.

All tissues of the body are susceptible to slight changes in the composition of the fluid which bathes them, and this is particularly evident in the case of the more highly organized tissues such as the brain. Mind, from the biological viewpoint, may be considered as a function of the brain—its most recently acquired and highly evolved function. As a living tissue, the brain is particularly sensitive to changes in the internal environment. It follows, therefore, that the brain, the organ of mind, can be affected profoundly not only by changes in hormone content of the blood and tissue fluids to which the nerve cells are exposed, but by changes in any of the physical, chemical or physiochemical properties of these fluids. Slight changes in subjective feelings, in thought and in actions of normal individuals from month to month, from day to day, and even at times from hour to hour, may be logically explained as the result of the reactions of the higher centers to slight changes in the internal environment.

Summarizing, it may be said that behavior of the individual would seem to be determined by three things: (1) what he comes into life with—namely, his hereditary background; (2) his external environment; (3) his internal environment. It is only through this last channel that the direct effects of hormones on human behavior can be manifested. Indirectly, hereditary factors and the external environment can, as we have seen, produce changes in the hormone patterns of the internal environment. Thus each of these three can influence behavior indirectly through the hormones.

THE LAWS OF MAMMALIAN EVOLUTION

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THE word "mammal" is an artificial term and has no vernacular equivalent in any language. Linnæus devised the word "mammalia" after the Latin "animalia"; and it was, as Dr. Gill used to say, one of Linnæus's happiest inspirations to bring together all mammals under a single heading. Formerly bats and whales were not supposed to be mammals, and there was a formal antithesis between man and beast, as though man were not a mammal himself. Thus "beast" and "quadruped" are not the exact equivalents of mammalia. The English form "mammal" was proposed by Dr. John Mason Good about 1813, who was very apologetic, not understanding that he was performing a real service to zoologists. Other languages also have artificial words for the same concept, such as the French "mammifère," the Spanish "mamífero." The Germans translate the term and call it "Säugetier"—the sucking animals But in all these and many other languages the word is purely artificial and derives from Linnæus's "mammalia."

The definition of the mammalia may be made a long and complicated story, but that is quite unnecessary. Two or three fundamental characteristics are quite sufficient to set the group off from the other vertebrated animals, such as reptiles, birds and fishes. As the term implies, mammals suckle their young, the possession of milk-glands being entirely uniform throughout the class. With the exception of the egg-laying monotremes of Australia, mammals bring forth their young alive and are not egg-layers. In the third place, mammals are without exception warm-blooded, a characteristic which they share only with birds. Finally, they are normally covered with hair, though a few animals, like elephants and hippopotamuses, have lost that hairy covering. The naked skin is invariably secondary. No other animal has hair, and even the seemingly hair-like appendages of certain birds are not really hairs but barbless feathers.

The marvelous story of mammalian evolution is recorded in the rocks, more especially those of the western part of North America and the southern part of South America Other regions have parts of the story in wonderful completeness, such as the Gobi Desert of Mongolia and certain deposits in Greece and France But no other part of the world has so continuous a record as the continents of the Western Hemisphere.

It is impossible in the time at our disposal to explain the method by which the rocks of the earth's crust are arranged in chronological order, and chronology is the foundation of the whole history of evolution. This is amusingly illustrated by an anecdote which I heard, but the truth of which I can not guarantee, of a foreign potentate who visited New York and was taken to the American Museum of Natural History and there was shown the series of fossil skeletons illustrating the development of the horses, from the tiny little *Eohippus*, no bigger than a fox, to the great modern draft horses. His guides took for granted that he understood the immensity of the millions of years involved in this history and took no pains to explain matters to him. When he returned to his kingdom (let us call it Zenda) he called his cavalry officers together and said: "The Americans have done marvels in horse breeding. They have built up large and heavy horses from tiny little creatures no bigger than a pointer dog. Now I want you people to get busy and turn our native pony into a cavalry horse.'' If chronology is ignored that proposal was entirely reasonable; but it is absurd from the point of view of time. The age of the earth is now estimated at about two billion years; but it is only within the latter portion of that vast period, say one hundred million years, that the development of mammals from reptiles took place, and the table which I have put on the blackboard will show you the major divisions of this latter part of the earth's history. These major divisions of eras, periods and epochs are valid for the whole world and are used in all continents; but many more subdivisions are required to show the details of the histories of the various mammalian families. No less than thirty subdivisions of the epochs of the Tertiary period are in current use; but these are local and seldom applicable to more than a single continent.

LATTER PART OF EARTH HISTORY

Cenozoic Era	Quaternary period—Pleistocene epoch	
	Tertiary period	Pliocene epoch
		Miocene "
		Oligocene "
		Eocene "
		Paleocene "
Mesozoic Era	Cretaceous period	
	Jurassic "	
	Triassic "	

The history of mammals begins in the Mesozoic era in the upper part of the rocks of the Triassic period. By the end of the era, the latter part of the Cretaceous, much the greater part of mammalian differentiation had been accomplished; and yet unfortunately that part of the story is the most fragmentary and the least understood because of the extreme rarity of Mesozoic mammals. Not half a dozen museums in the world have any representation of them. Then, too, Mesozoic mammals are all small, most of them minute, and are known almost entirely from jaws and teeth. While much may be learned from such organs, they give a very incomplete account of the faunas. It was in the Tertiary that the amazing blossoming out of the mammals into their extraordinary variety was carried out, so that now they fill a wonderful number of different rôles adapted to radically different habits of life. Most mammals are terrestrial—live on the ground; many are arboreal, living chiefly or exclusively in trees; others are burrowing and live underground; another category is the aquatic mammal which lives chiefly in the water, such as hippopotamuses and otters; some live in the sea, like seals and walruses that go ashore more or less frequently; while whales and their allies, porpoises, dolphins, etc., are so thoroughly adapted to the marine mode of life that they never go ashore and even stranding is fatal to them. Then finally we have the flying mammals, the true fliers like the bats and the gliders like the flying squirrels, and other groups which by means of a fold of skin spread between the four legs are able to take most prodigious leaps, as much as 80 yards, from the top of one tree to the foot of another. If an engineer were asked to design a locomotive, a tunneling machine, a trench digger, a steamboat, a submarine and an airplane, and use only modifications of a single design, he would say that such a task was utterly impossible or at best could produce only unsatisfactory makeshifts. Yet that is just what evolution has accomplished, because throughout the whole class there is the most complete and unmistakable unity of structural plan. The smallest known mammal, the shrew (a little insectivorous creature no bigger than your little finger), an African elephant or a ninety-foot Greenland whale, all have the same skeleton, modified according to need. The mole is a wonderful tunneling apparatus, and his fore feet are perfectly adapted to this operation; yet the bones and the number of them and their arrangement are the same as in the arm and hand of a man.

There is an obvious reason why this marvelous differentiation and diversification did not begin until the latter part of the Mesozoic era, and that is the question of food supply. Before the latter half of the Cretaceous period the land vegetation of the earth would not have supported a population of large mammals, or even those of medium size. Practically *all* our foods—with the exception of mushrooms, which are very innutritious—are derived from the flowering plants, and these did not come into existence until the late Cretaceous. They are therefore the condition precedent to the development of mammals; and when the great differentiation and spread of this type of vegetation took place, it gave mammals their chance, and they took an astonishing advantage of it.

The story of mammalian evolution is deduced from the data of paleontology. Having a succession of fossils in chronological order, we are able to deduce the method or mode of their advance. The principle is precisely the same as that employed in almost all historical researches, whether of archeology or the study of manuscripts and handwriting or any other inquiry of the sort. The prehistoric archeologist uses pottery as a means of dating his discoveries, having once learned the order of change in pottery designs from a series of datable remains. The paleographer, or student of manuscripts, does the same for changes of handwriting. He ascertains the method of change by studying a series of dated manuscripts. Every one, even though without experience, can identify handwriting of the eighteenth and seventeenth centuries at a glance, but the paleographer can do much more than this. He can determine, usually within a decade, the time at which an undated manuscript was written. My colleague, Dean West of Princeton, many years ago was invited by the Grolier Club of New York to prepare a new edition (Latin and English) of Richard de Bury's "Philobiblon." De Bury was bishop of Durham in the fourteenth century and wrote this treatise on books which was exceedingly popular, and of it a great many copies were made, and every copy means a fresh crop of errors. The writer copied all the errors of his predecessor and added some of his own, until the text of the little treatise became entirely corrupt. Dean West got hold of one manuscript which was remarkably clear and free from copyist's errors, but it was undated In order to determine its date, he took it to Oxford and submitted it to two famous scholars, and he was told in advance that their dates would differ by ten years, and so it proved. I do not remember the figures, but we may arbitrarily assume that one fixed the date 1450 and the other as 1460. After this a hidden date was discovered within the manuscript itself, and it turned out to be 1455 That, of course, was a lucky chance. Such accuracy as that is not ordinarily attainable. But the method is clear; it is that of first ascertaining from dated manuscripts the order of handwriting changes, and having learned that order, it can be applied to the solution of the undated copies.

That is precisely the method which we use in paleontology. We learn the order of succession, and that is given us by the geology or stratigraphy of the rocks in which these fossils occur, and from this we construct genealogical series of ancestors and descendants. No doubt they are but rude approximations to the truth, yet nevertheless they give us the the steps of change in their true chronological order. From these series we may deduce the laws of change. "Law" is perhaps an unduly ambitious term. It would be more modest and more accurate to say the "mode" of change. We find in the first place that the usual method by which one group is derived from another by "descent with modification" is divergent; that is to say, one group gives rise to several others which are unlike each other and grow less and less like with the progress of time. The usual history of two successive divisions of the geological scale is that a large proportion of the mammals of any one time die out, and that the population of the next time division is derived from a few survivors, giving rise to divergent groups, plus a certain number of other groups that have been supplemented by immigrants from some other region. That involves the great mystery of extinction. We are as yet entirely unable to account for the immense extinctions that have swept over the earth from time to time. The greatest example of this among vertebrated animals is the extinction which brought the Mesozoic era and the Cretaceous period to a close. The Mesozoic was the age of reptiles, of which there was an incredible variety adapted to all modes of life, and dominating the land, the sea and the air, and ranging in size from tiny lizards to vast dinosaurs, filling the sea with sea dragons and the air with Pterodactyls. And yet, with what seems to be startling suddenness, this immense assemblage was swept away all over the earth, leaving only the four groups of modern reptiles, snakes, lizards, turtles and crocodiles. In the Mesozoic there were twenty-five orders as contrasted with these four. No doubt the actual dying out of these creatures was much more gradual than it seems. The apparent suddenness is largely due to interruptions in the record. If we were reading a book of history and came to a place where half a dozen chapters had been torn out, the change of subject would seem abrupt. It must have taken place at any event in a comparatively short period of time; and no one has the remotest idea as to what brought about this revolutionary change. A somewhat similar extinction took place among the mammals at the end of the Pleistocene epoch, the epoch which immediately preceded our own time, and which ended with the disappearance of the Glacial ice from the northern continents. That extinction was by no means so world-wide. It affected only about three fifths of the land surface of the earth, the warmer parts of Asia and Africa escaping its effects. But in the Northern Hemisphere the destruction was only less complete than that of the Mesozoic reptiles. There is a remarkable record of Pleistocene mammalian life preserved in the tar pools of California; and there in the Los Angeles Museum may be seen an assemblage of mammals incomparably richer than that of the present day in North America: great numbers of elephants of various kinds, including the mastodon; huge cats which, for want of a better name, are called California lions; the terrible saber-tooth "tigers"; gigantic wolves; different species of horses, llamas and camels; a dozen different kinds of bison, some of them with a spread of horns of six feet; gigantic beavers as big as black bears; the grotesque and gigantic ground sloths, altogether extinct now, which were, like the equally grotesque armadillos and glyptodonts, immigrants from South America. This incredibly rich fauna was decimated by these mysterious extinctions; and while we can not explain them, we can see that the extinctions were not undiscriminating, that they followed a method, and that method was elimination of the extremely specialized forms, including, for example, the elephants, which in the Pleistocene covered every continent except Australia and now are found only in tropical Asia and Africa. Not only is their area thus reduced to less than one third of what it was in the Pleistocene, but the number of different forms is cut down to one tenth of the Pliocene and Pleistocene figures. Nebraska is the particularly rich graveyard of North American elephants and mastodons. As Professor Barbour, of the University of Nebraska, has said, almost any disturbance of the soil in Nebraska will turn up an elephant.

The feature which particularly distinguishes Pleistocene mammals is gigantic size; but all these huge, fierce and terrible forms were wiped out as if their life depended upon the Glacial ice, which of course it did not, though climatic changes at that time may have been an important factor in bringing about these great exterminations. But the same principle holds as far back as we can trace the story. At every break in the record, every pause, the huge and highly specialized animals died out; the smaller and more moderate ones continued and diversified and gave rise to new faunas. The record in the Gobi Desert is particularly illuminating of this principle Mongolia had a flair for the colossal. The most stupendous land animal that ever lived is the rhinoceros *Baluchitherium,* skeletons of which were obtained by the American Museum parties in their expeditions to Central Asia There has lately been finished in the American Museum a life-size mural relief of *Baluchitherium,* and the incredible creature stands sixteen feet high at the shoulder. The largest existing African elephants very rarely exceed twelve feet in height. Yet all these great monsters died out at successive times. One can see that the more perfectly and nicely adapted to its environment any animal is, the more fatal will any change in that environment be; and that is perhaps the reason for this selective extinction, though the extinction itself remains a mystery.

A second kind of evolution is parallel development, which may be called for short parallelism. This means that related groups continue for long periods of time to follow parallel lines of evolution, yet without any crossing or mixture of blood. The late Professor Cope first observed this phenomenon among the North American camels, in which family he discovered many tribes or phyla that kept very exact pace with one another, undergoing similar modifications, and finally dying out one after the other.

Certain philologists have contended that the various dialects and forms of the German language are not to be typified by a main trunk and branches, as is usually done, but rather by parallel channels of water of which no common source is discoverable, but which pursue their parallel courses throughout the history of the language Whether or not this is an acceptable view of the development of the Germanic dialects, it is an excellent picture of the parallel development of tribes within a family. Darwin himself recognizes the probability of such parallel evolution by saying that allied species with similar physiological constitution might be expected to go through similar cycles of variation. But parallelism is much more comprehensive than this and takes in, not only species, but families and orders, as is beautifully illustrated by the history of the horses on one hand and of the swift running ruminants on the other, as will be seen more particularly in a few moments.

The third type of development is convergent development or, in briefer form, convergence. By convergent development is meant evolution in which more or less similar forms are more nearly alike than were their ancestors, and is thus the exact opposite of divergence. The possibility of this was long denied by zoologists, chiefly in the interests of the theory of natural selection with which it seems to be incompatible. Now the pendulum has swung to the opposite extreme and convergence is overworked, many writers finding in it a convenient means of setting aside resemblances and relationships which do not suit their views. Now, first, for some illustrations of this principle. It can be affirmed with great positiveness because, in cases to be cited, each step in the development can be actually observed So far as single organs are concerned, like teeth or feet or skull structure, the number of cases of convergence that may be cited is unlimited. One of the most remarkable instances which may serve as an illustration of the principle is the astonishing saber-tooth marsupial (*Thylacosmilus*) lately discovered in Catamarca, an Argentine province, by my friend and one-time pupil, Mr. E. S. Riggs, of the Field Museum in Chicago. This great skull is wonderfully like that of the Pleistocene saber-tooth cat *Smilodon,* which is so exceedingly abundant in the tar pools of Los Angeles. Not only are the upper canine teeth converted into huge sabers, but the lower jaw has developed on each side a bony flange for the protection of the tusks. The general appearance of this skull is deceptively like that of the California saber-tooth; and yet the creature is not a cat, is not even one of the Carnivora, but a Marsupial nearly related to the opossums and the "Tasmanian wolves" so-called. But convergence may go even further than this and involve not simply skull and teeth but the entire skeleton. In South America in the Miocene of Patagonia there is abundantly represented a family of the exclusively South American order Litopterna, which is so extraordinarily horse-like that many paleontologists have insisted that it must have equine relationships and be included in the same ordinal group as horses. This idea has been now very generally abandoned, and the family accepted as one of the most striking cases of convergent development known. Every bone and almost every tooth is horse-like, and in some respects several genera of this family actually surpassed the horses in the completeness of the reduction of the toes to a single one. The modern horse, it is true, has but a single functional toe, the third of the original five, but, in addition, retains the remnants of the second and fourth toes in the shape of long "splint bones," which are not visible externally. But the mock horses of South America have reduced the splints to vestiges no larger than a split pea, making the most perfect monodactyl creatures ever discovered.

The question naturally presents itself, How far may convergence extend? And a partial answer at least is given by the fact that it never amounts to identity or exact similarity. While every bone and nearly every tooth of this Patagonian horse-like creature resembles the corresponding parts of true horses, especially those of the three-toed kinds found in the North American Tertiary, no competent anatomist would confuse one with the other. There is a marked similarity throughout, but nowhere an exact similarity.

Time forbids the enumeration of more cases of these kinds of development—divergence, parallelism and convergence. The latter two modes of development are less common. Divergence is the normal, usual one, so far as the records have yet been deciphered.

We may now take up one or two lines of descent which have been most satisfactorily deciphered from the story in the rocks. The case of the horses has been so often cited that many paleontologists are tired of it and make mock of it, as though an assertion were rendered untrue by repetition. This story, which is the most complete yet ascertained in the history of mammalian families, begins in the early Eocene and continues to the present day. No doubt its actual beginning in the Paleocene will some day be brought to light. The earliest horse known as yet is the little *Eohippus* of the Lower Eocene, a creature no larger than a fox or greyhound, with short neck, short limbs and feet, long body and tail, with four toes on the fore feet and three on the hind, and with teeth of a very simple pattern, low-crowned, forming roots immediately after eruption, so that no further growth is possible. In each of the thirty odd subdivisions of Tertiary and Quaternary times there is found the characteristic horse genus of that subdivision, together with branches which came to nothing in the long run but which display step by step modification. Each genus is composed of larger animals than the preceding one, so that there is a steady increase of size. The neck grows steadily longer; the limbs and feet are gradually elongated in each successive stage. Of the bones of the forearm and lower leg, the outer one is reduced, the inner one enlarged so as to carry the whole weight, and eventually the two co-ossify into what is functionally a single bone. The number of toes is reduced, first to three in each foot; then the median, third toe enlarges and the second and fourth diminish until they become mere dew-claws and finally lose their external portions so that only splints remain, and these shrank and grew shorter with time The teeth take on an exceedingly complicated pattern and continue to grow throughout life; because midway in the history the horses took to grazing, living principally upon grass, and grass is an extremely abrasive substance, which wears teeth down very rapidly; and if the life of the individual were not to be unduly shortened, it was necessary that the teeth should continue to grow and make up for the loss by wear. The skull and jaws are remodeled to make room for these greatly elongated teeth. Throughout nearly all their history the horses were very light and slender, having much the proportions of deer or antelope: but late in the Tertiary, in the Pliocene epoch, they began to take on the sturdy build of modern horses without losing the grace and beauty of equine proportions. The whole object, so to speak, of equine development is, as Huxley phrased it, to form a "cursorial machine," which the horse preeminently is.

The swift-running ruminants, whose history is not known with quite such fullness and exactness and yet with a considerable degree of completeness, parallel the horses in this development for speed, and step by step we may follow the progressive elongation of the neck, the shortening of the trunk and tail, the elongation of the limbs and feet and the reduction of the toes. In the ruminants and their relations the limit of reduction is two; and yet they overcome this to a certain extent by fusing the two long bones of each foot into a single cannon-bone, though the visible toes remain separate, which gives the appearance of a "cloven hoof"

A totally different type of development we find among very heavy and massive animals, such as the elephants, rhinoceroses, hippopotamuses and several extinct groups of hoofed animals, which show a very similar mode of development In each of these lines, the hippopotamus excepted, we may trace the developmental steps, and in them there is a similar increase of bodily size and weight to a bulk much greater than that of horses and ruminants, rising in the larger individuals to several tons and presenting a mechanical problem which is very different from that of the swift-running types. In all these massive forms we find that reduction of the toes stops at the point reached when great increase of weight began; as five in the elephants, four in the hippopotamuses and three in the rhinoceroses. In all these heavy forms the feet remain short, the limb bones are unreduced and never co-ossify, the neck is short, the trunk very long, and the skull develops a huge mass of sinuses or connecting cells which protect the brain. This reaches a maximum in the elephants, so that much knowledge and skill are required to put a bullet into an elephant's brain. In the largest and heaviest of these animals of most of the different groups, the leg bones lost their marrow cavities, which are filled up with spongy bone, increasing the strength of the bone without enlarging its diameter.

These are two types, then, of mammalian evolution so far as the hoofed animals are concerned. Development of the Carnivora, to say nothing of the flying types, took place along entirely different lines, because the mode of life and habits of taking food are so radically different. But the fact remains that all these lines of modification, while differing so much in detail, follow similar principles, which may be formulated and which constitute the "laws" of mammalian evolution.

In the first place, specialization takes place by loss of parts. The earlier mammals had the maximum number of teeth, of vertebrae, of toes; and while we can not assert with definiteness that no additional tooth or toe or vertebra was ever developed, yet it may be said that that is not the normal method of modification, but a very rare exception. The earlier mammals of the Paleocene and older Eocene had the maximum number of these parts, and in each successive stage of geological time in the progressive groups this number was reduced. In all the placental mammals of the early Eocene the number of teeth is 44, which in ourselves is reduced to 32, and every genus or species almost has its own characteristic number. The only cases of tooth addition are those of the toothed whales and certain armadillos. A porpoise or a dolphin has several hundred teeth, a number far in excess of the ancestral types, which had only 44. But here the increase in parts is accompanied by a complete simplification. The teeth are remarkably peg-like without any modification whatever. Of the normal type of mammal teeth, there is but one case of probable addition in number, and that is the long-eared fox of South Africa (*Otocyon*), which has four molars instead of the normal number of three. How this exceptional condition arose can not be stated until the history of the genus has been ascertained; but it looks like a case of addition and, if so, is unique. Elsewhere reduction in number is the invariable rule. This reduction in number is accompanied by enlargement and specialization of the parts retained. The horse's foot, for example, is far more elaborately constructed than the foot of a rhinoceros or a tapir, because reduction to a single digit makes necessary greatly increased strength in the joints, and we find elaborate arrangements to prevent dislocation. A very perfect illustration of the enlargement and specialization of parts remaining is given by the lower shearing teeth of the lion or tiger or other large cats. In the ancestral form, as may be demonstrated, this tooth had five cusps· an anterior shearing triangle of three and a lower posterior heel of two. One by one these cusps are reduced, until there are only two of the original five remaining, forming part of the shearing triangle, while the heel disappears altogether. These two cusps are greatly enlarged, made thin and sharp-edged, and form, with the corresponding upper tooth, a most perfect shearing apparatus. A lion can bite through a horse's leg as though it were a stick of macaroni. This, however, is only one method of tooth modification A less common one is the addition of cusps, and the most perfect example of this is the grinding tooth or molar of an elephant, which, as has been shown, arose from a smaller tooth of four cusps. In the last molar of the elephant we may find as much as 25 or 30 plates of alternating dentine, enamel and cement; but the teeth are of such immense size that only two can find room at the same time in each side, above and below, making a total of eight. There are other cases of this same sort, like the water hog or capybara of South America, which is the largest of existing rodents and which has almost as enlarged and complicated a tooth as an elephant. The wart hog of Africa also imitates the grinders of the elephant. But the more common method, as explained, is by reduction of parts and specialization of those which are retained. It is only in the teeth that we find additional elements. In all other parts of the body reduction is the rule. For instance, no existing Perissodactyl (the horse, tapir and rhinoceros group) has more than 23 vertebrae in the trunk. In the Eocene period we find 25 to 30, and all the early members of every order have long tails, which are retained in full length only by the great cats. All others have diminished their tails, and many have lost them altogether.

Another principle is the one enunciated by the late Professor Dollo, of Brussels; namely, the irreversibility of evolution. This may have exceptions, but it is undoubtedly the general rule. A part or organ once lost is never regained, so far as we know. It has been done by artificial breeding, as Professor Castle, of the Harvard Medical School, has bred four-toed guinea pigs, though their wild ancestors as well as all the domesticated forms, are three-toed. But there is no reason to believe that this happens under natural conditions. If so, it is the rare exception.

The question arises, What is back of all this? What is the driving force that has produced this astonishing development and diversification? And the answer must be: We do not know. Darwin's theory of natural selection did offer a solution of the problem, and many naturalists still retain a belief in this theory. It has, however, steadily lost ground; and paleontologists especially have never been satisfied with it, because it seemed incompatible with the phenomena of parallel and convergent evolution, which have been so fully demonstrated. It certainly seems impossible that selection of random variations in unrelated lines should have produced such likenesses as the saber-tooth marsupials and the mock horses of South America But in giving up the theory of natural selection we have nothing to put in its place and it does not seem likely that we ever shall have; though he is either a very foolish or a very bold man who would undertake to set limits to the possibilities of scientific discovery.

PLANTS AND CIVILIZATIONS

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"ALL flesh is grass," an ancient scriptural saying, is essentially true, for as all herbivorous animals are directly dependent on plants, so, once removed, are carnivorous animals dependent on the vegetation, even as is man. To a very large degree our present civilization is based directly or indirectly on plants, and its continuance, in ultimate analysis, is definitely dependent on the plant kingdom. These evident truths are merely stated to explain or at least to justify the caption, "Plants and Civilizations."

There is an interesting corollary between the development of the various types of vegetation in past geologic times and the types of animals characteristic of each geologic period In the past, as now, the animals of each epoch were dependent on the available food supply, and at all times the vegetation was the primary source. It was not until after the modern types of vegetation were developed, in the Cretaceous and in the Eocene of the Tertiary, that the mammals, the highest group of animals, could become dominant, although they appeared in geologic time some millions of years earlier. Previous to the development of the grasses, the chief type of plant that will thrive under constantly heavy grazing, the food supply of the herbivorous mammals was distinctly limited. The Eocene, the oldest period of the Tertiary, commonly designated "the dawn of the recent," was the dawn of the recent only in so far as the animal life was concerned. Most of the modern types of flowering plants were even then extant and widely distributed, many of them having originated in the Cretaceous.

One can hardly say just how long man has been present, but there is clear evidence that he existed as a very primitive individual in the Tertiary. It was not, however, until some time during the Pleistocene that he commenced to become a dominant factor, and even here the term dominance is relative. Man's early progress was exceedingly slow. As long as he remained in the primitive stage of nomadism, having no fixed place of abode, dependent for his daily food entirely on hunting, fishing and such edible portions of wild plants as were available to him, little definite progress was possible. Thus dependent on nature for his daily food, he must, of necessity, follow a nomadic existence, for such a food supply is not constant, varying from season to season, involving the necessity of moving from place to place in search of it. It was only well after agriculture had become a definitely established art that anything approaching what we call civilization was possible, for agriculture is and always has been basic to advanced cultures in all parts of the world. All early civilizations are proofs of leisure, provided by a permanent and dependable food supply, as well as of innate capacity on the part of the pioneers of civilization, no matter where located.

The claim is frequently made that astronomy is the oldest of the sciences, but this may be challenged if we admit that agriculture and a wide knowledge of the economic uses of plants are sciences. Before even the most primitive agriculture could be developed, man must have acquired a vast fund of knowledge about plants, their properties and uses; botany, if you will, or at least economic botany. Essentially this knowledge must have been empirical, acquired in part by the method of trial and error, in part by direct observation, but it was cumulative. This applies to plants yielding edible fruits, seeds, tubers, vegetative parts and even flower-buds and flowers; to those yielding poisons, medicines, fibers, gums and resins; and even to those yielding timbers adapted to this or that particular need. It was only on the basis of a very wide and intensive empirical knowledge of plants, their products and their uses, that primitive man could possibly develop even the beginnings of agriculture, and these beginnings must have antedated anything that we should recognize as civilization by many thousands of years.

Ethnologists recognize various periods in man's development from a thoroughly primitive nomad through various stages to what we call modern civilization. For several million years little progress was evident. Conservative ethnologists place the beginnings of culture at approximately the opening of the so-called Ice Age near the close of the Tertiary. In terms of geologic time, as now estimated, this was about 1,000,000 years ago, but even at this remote period crude stone implements were in use. Man's actual presence on the earth long antedates this period.

For most of this million years upward progress was very slow. Beginning perhaps between 20,000 and 30,000 years ago, but probably earlier, more definite advances were made. The use of fire, the construction of shelters, the use of clothing and bodily ornaments, the practice of various ceremonies, primitive sculpture, formal burial of the dead, are some of the factors involved in a very slowly unfolding civilization.

Then came an economic revolution of the greatest significance for the future of the human race. Possibly between 10,000 and 15,000 years ago, but probably earlier, although some authorities allow only 8,000 to 10,000 years, agriculture became an established art, and the primitive civilizations based on this early agriculture became an established way of living. This primitive agriculture was merely the successful domestication of certain basic food plants in certain parts of the world, followed later by the successful domestication of certain animals. This step or these steps thus supplied the pioneers of civilization with the advantages of a permanent and dependable food supply Thus sedentary life became possible, and a certain amount of leisure resulting from the division of labor enabled those individuals endowed with the proper mental capacity the opportunity to devote time and thought to other than the previously dominant factor of providing the necessary daily food.

The probability is that the actual cultivation of plants preceded the domestication of animals, for animals under close domestication must be provided with food. Possibly in some parts of the world man did follow his flocks and herds before he actually commenced tilling the soil, but it was the actual planting and care of crop plants that definitely removed man from the nomadic class and provided the basis on which higher civilizations could be developed. To become a successful agriculturist involved a definitely fixed abode. There was thus gradually developed in certain strategic centers an agriculture based in part on plants, in part on animals, depending on the people, the location, the climate and on what was available for domestication.

What we call civilization is so complex, and the factors that have encouraged or permitted its development are so diverse, that manifestly one can not truthfully claim that any single factor has been the deciding one, permitting or encouraging this or that development. The use of implements, the application of fire, the use of clothing, the construction of shelters, the development of metallurgy, the use of stone in construction of buildings, the invention of writing, are all important factors, each in its own way essential to further advances.

If, however, there be any single factor that has permitted or encouraged the development of civilization over and above all others, it is probable that agriculture should be given this credit. Just when agriculture was first practiced we do not know, but we can approximate the places where its development first became manifest. Just how the discoveries were made that certain food plants could be profitably grown is immaterial —they were in any case unquestionably accidental. Agriculture is not the invention of any one man or any one people, but numerous individuals in the dim past and among diverse peoples in various parts of the world have contributed to it, now in this direction, now in that. Let it be emphasized here that modern man has not added a single basic food plant or domesticated animal to the long list of those selected and tamed by prehistoric man, for every important species was already in domestication somewhere in the world at the dawn of recorded history.

In tracing the origin of cultivated plants many factors are involved. Plants long in cultivation have by selection and hybridization frequently assumed strikingly different and reasonably fixed forms, as indicated by such common vegetables as the cabbage, kohlrabi, Brussels sprouts, kale and cauliflower, all derived from the native European *Brassica oleracea* Linn. It is therefore sometimes difficult to prove that this or that feral type is really the parent form of this or that cultivated plant. Were such distinct forms as those of the *Brassica* mentioned above found in nature as wild plants, most botanists would unhesitatingly accept them as distinct species. Convincing evidence is that provided when we find the parent species growing in its native habitat and can positively prove that it is the wild prototype; but here one must constantly be on guard, because cultivated plants introduced into remote regions even in modern times have frequently become naturalized in their new homes and from their present occurrence appear quite or almost as though they were indigenous species in their new homes. The wild ancestors of nearly all cultivated plants are now known and we can with confidence state that this species is a native of that region and that that species comes from Mexico or Asia Minor or China, as the case may be. Even when we do not actually know the wild parent of such important cultivated plants as tobacco, maize and the common garden bean, we can with confidence state that they originated in some part of North or South America, and that the coconut came originally from some part of the Old World tropics.

Wolff in 1932 discussed the process by which plants were and still are brought under domestication. He states:

> Among the cultivated plants there are such ones which have entirely lost their connection with the wild flora, which not only do not occur themselves in wild state, but for which it is difficult even to ascertain the initial forms. To the second category belong species whose connection with the wild representative may be readily traced, but which themselves are not met with in wild state. Both are cultivated plants in the full meaning of the word. As already mentioned in the preceding chapter, they frequently have so much changed their biological features in cultivation that they have entirely lost the faculty for an independent existence, without the support of man.
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> Finally the third category is formed by plants still met with in wild state, either in the region of cultivation itself, or in places frequently not distant from it. In this case we have to deal with wild species, little altered or quite ûnaltered by man, which might be more correctly called "grown" species, in op-

> position to the above mentioned "cultivated" species.
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> From this category there is but one step to the wild species utilized by man in wild state, by way of gathering the plants or their products. This is the first stage in the origination of cultivated plants, which for some of them is connected with the present day while for others it has become a remote past.
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> The origin of the cultivation of any plant must be thought of as a series of successive stages of domestication, through which the given plant passes. Beginning with the accidental acquaintance with the plant in its wild state, with subsequent deliberate gathering of its products, and finally its intentional introduction into cultivation and gradual selection of the forms most valuable for man—such are the stages through which every cultivated plant has passed, and still passes, in its evolution. At the present time all these stages of the transformation of a wild plant into a cultivated one may be simultaneously observed. Thus we have a series of plants which are utilized by man simply by way of gathering them—it suffices to mention the medicinal plants, different fruits and berries as well as many technical plants, etc. We can cite a series of examples of the utilization of stands of wild-growing plants by way of certain improvements, cultivation of the soil, application of fertilizers and the elimination of other species growing promiscuously with them. We are able not only to trace, but to observe at the present time the transformation of the wild growing weeds admixed to the crops, into cultivated plants.

A brief survey of the approximate places or origin of cultivated plants and of domesticated animals emphasizes the striking fact that most of the plants and animals, and all the really important ones, came from certain restricted areas in North and South America and Eurasia. These regions are essentially the highland of Mexico and contiguous areas in North America; of Peru, Bolivia and Chile in South America, and in Eurasia certain parts of China, northern India, Central Asia, Asia Minor and perhaps Abyssinia.

These limited areas that supported the wild ancestors of our present-day cultivated plants and domesticated animals form only a very small percentage of the land surface of the earth; all North America north of Mexico, most of South America, most of Africa, all Australia, and most of Europe and Asia contributed nothing of importance.

It should be noted that the centers of origin of agriculture and of civilization are in general characterized by an equable type of climate, without great extremes of heat and cold, and in general with a restricted rainfall. They are to be classed as subtemperate or subtropical, rather than as temperate or tropical, presenting from the standpoint of primitive man neither the rigors of the colder temperate regions nor the equally evident disadvantages of the deep tropics.

Even more impressive is the fact that those centers in whch ancient civilizations developed, whether in the Old World or in the New, are the same as those wherein our basic cultivated food plants and domesticated animals originally occurred as feral species. There is thus a very close correlation between the places of origin of cultivated plants and domesticated animals and the places of origin of early civilizations. It becomes manifest that in each ancient center certain cultivated plants formed the basis of the food supply on which each ancient civilization was based, in each case the basic species being supplemented by secondary ones Thus in Mexico may be listed as basic species maize, beans and the sweet potato; in Peru the potato, maize and beans; in Central Asia, Asia Minor and perhaps very limited parts of the Mediterranean basin certain cereals, including rye, barley, wheat and oats; in India and China rice and perhaps millet and sorghum. In all centers the secondary sources included certain local fruits, vegetables and root crops; meats, dairy products, and fish must of course be added.

Thus far little but general principles have been considered. What follows is largely an attempt to apply our knowledge of the origin of cultivated plants to that very intriguing and much discussed problem of the origins of the pre-Columbian American civilizations.

If one compares pre-Columbian American agriculture with that of Eurasia with an unbiased mind, carefully weighing the biological evidence, he will reach certain very definite conclusions regarding man and his activities in America. It is an incontrovertible fact that agriculture originated in America on the basis of strictly native American plants and animals, not one of which was known in Eurasia until after 1492, even as not one of the more numerous cultivated plants and domesticated animals of Eurasian origin, except the common dog, was known in America until after the same date. The significance of this statement is not fully realized by various theoretical historians, some anthropologists and numerous popular writers. It supports in a remarkable manner the belief of most conservative anthropologists that man reached America from Asia as a primitive nomad; that once here he developed his civilizations *de novo* on the basis of a wholly new agriculture that in turn was based on strictly native American plants and animals.

DeCandolle's conclusions on the origins of cultivated plants as expressed by him in 1883 are essentially correct. In the case of a few individual species his findings have been challenged, but in no important one has he been shown to be in error. In reference to the bearing of cultivated plants on Eurasian-American civilizations he merely states: "Dans l'histoire des végétaux cultivés je n'ai aperçu aucun indice de communications entre les peuples de l'ancien et du nouveau monde avant la decourverte de l'Amérique par Colomb." The facts were so manifest that further discussion of the matter seemed to be necessary.

The same idea was expressed by Cook in 1925 in the following words: "That the agriculture of the native peoples of the North and South America was not introduced from the Old World but had an independent indigenous development, is demonstrated by the fact that American agriculture was based on native American plants."

In 1931, Vavilov thus states the case: "Agriculture in pre-Columbian America has originated quite independently of the Old World. If the peoples of the New World have come from Asia, as is supposed by the majority of investigators, they have certainly come without the cultivated plants of Asia. The introduction of the wild plants into cultivation was a perfectly independent process in the New World."

These conclusions will not be acceptable to certain representatives of that school of anthropologists known as the diffusionist. They maintain the hypothesis that culture originated in one place and that by direct or indirect contacts it was spread over the world. The extremist apparently does not admit the possibility that an art or a striking advance in culture could possibly originate independently in different parts of the world. Yet this problem of American versus Eurasian agriculture supplies incontrovertible evidence that this art or science, an activity absolutely basic to civilization, did originate in America independently of Eurasian contacts; and if such a complex science or art as agriculture has thus been independently developed in remote centers, then why should we not accept the idea in reference to architecture, sculpture, hieroglyphics and other arts of civilization? It must be remembered that, relatively speaking, agriculture was just as highly developed in pre-Columbian America as it was in Eurasia, involving not only the selection and domestication of plants and animals, but also the art of plant breeding, the adaption of plants to varying climatic conditions, the use of fertilizers, construction of extensive terraces and the application of the art of irrigation.

There is even the possibility that agriculture may actually be older in America than it is in Eurasia, a point that can not be definitely settled. Supporting this idea is the fact that for the Eurasian cultivated plants the actual wild prototype of each is known with reasonable certainty; yet in America, the wild forms of such important plants as tobacco, maize, the garden bean and several other species are not with certainty known. As expressed by Cook: "The much closer resemblances between the domesticated and wild forms in the Old World as compared to those of America, suggest that domestication has taken place in the Old World more recently than in America; and that the biological factors indicate a greater antiquity of agriculture in America than in the Old World."

If man reached America over a northern route, as he unquestionably did, he came as a primitive nomad dependent on hunting and fishing. Even if he had any knowledge of agriculture in Asia he would have entirely lost that knowledge in the many generations involved in his occupancy of the New World. He brought no crop plants with him from Asia because the climatic conditions in the northern part of his route of migration are inimical to agriculture. As a matter of fact, man probably left Asia on his American adventure before the development of agriculture in that part of Asia whence he came or with which he was familiar. As he advanced southward in America, he eventually came in contact with native food plants, and in the course of time, unquestionably involving many generations, he selected and adapted certain species to cultivation; but nothing even approaching agriculture was attempted before he reached the native homes of the plants he later learned to utilize; and this means Mexico, for no important cultivated plant of the pre-Columbian American agriculturists was originally native of that part of North America north of Mexico.

A striking fact in support of the general thesis that man entered North America as a primitive nomad, bringing no agriculture with him, is that among the domesticated animals the only one common to the two hemispheres in pre-Columbian times was the common dog, and the dog would naturally be the one animal that a primitive nomadic hunter would bring with him in his migrations. We have already seen that no cultivated plants and no other domesticated animals were common to the two hemispheres until after the close of the fifteenth century.

It was perhaps but natural that the early European explorers of North and South America should attempt to explain what they found here on the basis of assumed ancient contacts between the peoples of the Old and the New World. Yet as early as 1670 Ogilby had clearly demonstrated that these assumptions were illogical, and even at that early date had concluded that man had reached America from Asia over a northern route. This was merely a logical deduction based on such data as were then available to him, in refutation of the fanciful ideas of preceding observers that the early American civilizations must have been derived from Eurasia. As a matter of fact, outside of those efforts of purely imaginative writers to derive early American cultures from hypothetical lost lands such as Atlantis and Mu, the ancient Egyptians, Phoenicians, Carthaginians, Mesopotamians, Greeks, Latins, Welsh, Irish and even the "lost tribes of Israel," have been invoked, as well as peoples of India, China and Japan, to explain pre-Columbian American civilizations.

As noted by Cook, historians and others (among whom I would class some anthropologists and ethnologists, particularly the diffusionists, and a much larger number of popular writers) who do not have a biological background may and often do fail to consider some of the most significant factors in locating centers of primitive culture. He emphasizes the fact, patent to all biologists, that the Mediterranean basin was not the site of an indigenous development of agriculture, because the most important crops on which the Mediterranean cultures were based were exotics, having been introduced in the prehistoric and historic periods from other regions.

Thus, to refute the claims of those diffusionists who claim that agriculture and civilization originated and developed in the Nile Valley, it is only necessary to indicate that not a single crop plant cultivated by the ancient Egyptians was native of the region; and the same statement is true for that other great center of development of early civilizations in southwestern Asia, the great Mesopotamian valley. Agriculture must have been a highly developed art somewhere in southeastern Asia, outside of the great valleys, long before man could adapt his agricultural knowledge to the different conditions existing in the great valleys of the Tigris, the Euphrates and the Nile. The "children of the sun," the hypothetical highly cultured pioneers of civilization of certain diffusionists in the Nile Valley, who there developed their civilization and thence extended it to the ends of the earth, are of interest merely in the sense of highly imaginative fiction. They have no more definite claim for acceptance than do the progeny of other imaginative minds that postulate an ancient Atlantis or an ancient Mu as the place of origin of ancient high cultures from which the civilizations of both Eurasia and America were derived.

The supporters of a hypothetical ancient Atlantis and the equally ardent but fewer supporters of the even more nebulous Mu should be mentioned in passing. The one postulates an ancient continent or island group long since sunk beneath the sea in what is now the Atlantic Ocean, and the other places ancient Mu in the Pacific basin. The supporters of both Atlantis and Mu explain all resemblances and pseudo-resemblances between the civilizations of the New World and that of the Old, whether in architecture, sculpture, art, or hieroglyphics, or in civil, ecclesiastical, or political organization, on the assumption of ancient contacts across these lost lands. They attribute, with no tangible evidence, a high order of civilization to the hypothetical peoples of these equally hypothetical areas. The extremists visualize the Atlanteans as the parent-colonizers of both the Mediterranean and Caribbean shores. That there are no indications of philological relationships between the languages of the peoples of these widely separated regions does not deter them in the least, and the simple biological fact that there were in pre-Columbian times no cultivated plants nor domesticated animals common to the two regions is not mentioned. The theory that Atlantis existed, and that its inhabitants were highly civilized, would entail a highly developed agriculture; but it would be a strange and utterly unexplainable phenomenon that this assumed parent-colonizing people to the two hemispheres transmitted to their supposed descendants in Europe and America not a single cultivated plant nor a single domesticated animal in common; just as strange and inexplicable as an assumption that this ancient highly civilized people had developed no agriculture.

Ogilby's conclusions regarding the non-existence of Atlantis as stated in his quaint language of 1670 are entirely logical, but have had little effect on the numerous imaginative writers who have argued in favor of Atlantis; they in general cite only those factors that support a pre-conceived hypothesis, ignoring all items that would cast doubt on the validity of their claims. He states:

> Here it will not seem amiss . . . to engage and search with some scrutiny concerning this America; First, whether at any time 'twas known by the Ancients? And next, by what People, and when first Inhabited? About the former, the Learned of these later times Jangle amongst themselves, for some of them will needs ascribe so much Honor to Antiquity, declining the Worthy Praise of those that made so wonderful a Discovery, as if they of old, and many Ages before, had done the same, or at least, that this New-World to them was not unknown, maintaining this their bold Assertion from the Authority of what they find, both in Ancient *Greek,* and *Latin* Authors: First, especially in the Learned *Plato,* who, as you know at large, describes a New *Atlantis,* lying beyond the *Straights* of *Gibraltar,* whose Coast is surrounded with two vast Seas that are sow'd thick with scatter'd Islands. By these Seas they understand the Atlantick and Southern-Sea, by the many Isles, *Cuba, Hispaniola, Jamaica, California,* and others, which lie sprinkled along the coast of *America.* But it cannot be made out, that *Plato* describes ought but a Fancy, his own Idea, not a Countrey that ever was, is, or shall be, though he sets it forth so Accurately, and with such Judgment, as if he had taken a Survey of the place, and found such a Land indeed.

He therefore dismisses the Atlantis theory and then proceeds to discuss the ideas advocated by earlier authors appertaining to assumed Phoenician, Carthaginian, Greek, Latin, Hebrew, Welsh and Chinese contacts with America in ancient times. He shows conclusively that on the basis of philology, customs and other factors such theories are untenable, as being largely imaginary, with no tangible evidence to support them. He reaches the logical conclusion that America was originally peopled from northeastern Asia.

It is a manifest act that all cultivated plants and all domesticated animals were derived, at some period in the history of the human race, from feral forms. It is a striking but incontrovertible fact that every basic cultivated food plant and every important domesticated animal, and practically all the secondary ones in both categories, were already domesticated somewhere in the world, at the dawn of recorded history. This merely means that these plants and animals were selected and domesticated by primitive man many centuries before he developed to the point of recording his activities.

While modern man has vastly improved both his cultivated plants and his domesticated animals and has evolved numerous new forms by selection and hybridization, he has not added a single item to the long list of basic species selected by his prehistoric ancestors, and but very few to the list of secondary species. Those plants that have been domesticated in the past hundred years or so are chiefly those yielding commercial products other than food, such as ceara or para rubber, cinchona and abacá, numerous ornamentals, and if food plants, then those of very secondary importance, such as the strawberry, blueberry, Concord and Catawba grapes. We may speculate as to whether or not it may be possible to develop important food sources from plants as yet never brought under cultivation, and while it may be admitted that such a development is possible, at the same time the probabilities are that the selections made in the dim past of man's history can not be improved upon.

Plants domesticated by primitive man naturally must have been developed in cultivation in the regions where they originally occurred as feral species. And it is well to emphasize, what all biologists know, that the vast majority of species of both plants and animals are of distinctly restricted natural distribution. In nature we find very few cases of universally distributed species, that is, those occurring naturally in both hemispheres and in both tropical and temperate regions. The cultivated plants and the weeds of cultivation form the bulk of these, and they are all man-distributed.

As conditions became more settled and as certain species of plants and animals were proved in domestication, both the plants and animals, and the art of caring for them, or agriculture, were transmitted from those who developed the art to their immediate neighbors. Thus gradually the art of agriculture spread from one people to another, enabling the recipients in turn to become more or less independent of the natural food supply and in turn to develop their own civilizations. In North America, for example, cultivated plants originating far to the south in Mexico, such as maize, field and garden beans, pumpkin, squash, sweet potato, tobacco and others, were found by the early European explorers to be more or less universally cultivated by the American Indians through the northern United States and in southern Canada. The plants selected and domesticated by the pioneers of American civilizations in Mexico, and the art of caring for them, had, long before the time of Columbus, been transmitted from one primitive group to another until they had reached the limits of possible cultivation northward. In spite of the very greatly developed modern agriculture in what is now the United States and Canada, practically not a single species of the many scores in cultivation is native to these regions, all having been introduced either in prehistoric or within historic times.

What was true of the early dissemination of selected cultivated plants and domesticated animals in America was also true in Eurasia. Basic cereals originating in Asia Minor or in Central Asia, such as wheat, barley, rye, oats, and less important ones, such as millet, Italian millet and sorghum, as well as other cultivated food plants, were spread over much of Europe, Asia and Africa long antedating recorded history.

Throughout the long prehistoric period of dissemination of cultivated plants and domesticated animals, and within the historic period up to the close of the fifteenth century, one is impressed by the fact that with one exception the selected plants and animals domesticated by early man, whether in Eurasia or in America, did not transcend the limits of the eastern or the western hemispheres.

The number of described species of plants is probably in excess of 250,000. Most of these are of no particular economic value. The number of cultivated agricultural plants, even including strictly forage plants, is relatively small, a few hundred at most, while what might be called the food plants basic to civilization are limited to a few score.

A brief consideration of the strictly American species of cultivated plants will give us some graphic idea of the important contributions of early man in America to modern agriculture. It should be kept in mind that in the following long and rather impressive list not a single species was known in Europe or in Asia until the close of the fifteenth century. America produced but one cereal, but that one the most important maize or Indian corn. Other important food plants were the potato, sweet potato, cassava, all varieties of field and garden beans, as well as the lima, scarlet runner, tepari and yam beans, tomato, pepper, sunflower, Jerusalem artichoke, squash, pumpkin, arrowroot, peanut, chayote, papaya, avocado, pineapple, custard apple, soursop, cherimoya, guava, cacao, cashew, sapote, white sapote, sapodilla, star apple and mamei. These are now widely cultivated in appropriate regions in both hemispheres, some being strictly tropical, others also extensively planted in temperate regions. Particularly in South America, a number of other native species were and are still grown for food, but which have not become of importance in other regions. They include the ulluco (*Ullucus*), oca (*Oxalis*), anyu (*Tropaeolum*), yautia (*Xanthosoma*), llacou (*Polymnia*), arracacha (*Arracacia*), achira (*Canna*), jataco (*Amaranthus*) and quinoa (*Chenopodium*). In Peru alone it is estimated that about 70 native species had been domesticated in pre-Columbian times, although some of these were not food plants, including cotton, tobacco and various ornamental and medicinal species. Yet there is much evidence that leads one to believe that Mexico and Central America are more important as an original source of food plants than are the South American centers.

American contributions to domesticated animals were comparatively few, the llama, alpaca, muscovy duck and guinea pig in South America, and in Mexico the turkey, exhausting the list.

Eurasia, particularly Asia as contrasted with America, yielded a very much larger number of cultivated food plants and domesticated animals. Among the latter may be mentioned cattle, the horse, sheep, goat, swine, water buffalo, yak, camel, goose, duck, hen, guinea hen and pigeon. With the exception of maize all the true cereals are of Eurasian origin, including wheat, barley, rye, oats, millet, Italian millet, pearl millet, sorghum, rice, teff, ragi and coix, while for convenience buckwheat may be placed here, although it is not a true cereal. Among the vegetables are the turnip, cabbage, rutabaga, rape, chard, mustard, radish, beet, parsnip, carrot, onion, leek, garlic, shallot, spinach, egg-plant, lettuce, endive, salsify, celery, asparagus, globe artichoke, pea, soybean, cow-pea, chick-pea, pigeon-pea, lentil, broad, hyacinth and asparagus beans, taro, yam, sugar cane, sesamum and various others. Among the fruits the apple, pear, plum, cherry, wine grape, apricot, peach, prune, olive, fig, almond, persimmon, quince, pomegranate, jujube, melon, watermelon, cucumber, and in the warmer regions the banana, coconut, orange, lemon, pomelo, lime, date, mango, breadfruit, jak fruit, rambutan, litchi, longan, mangosteen and various others. Practically all the cultivated forage crops, including the hay grasses, clovers and alfalfa, are also of Eurasian origin.

In modern times, with steadily improving intercommunication between various parts of the world, man has become the most important single factor in the actual dissemination of plants. It can not, however, be too greatly overemphasized that it was not until after the discovery of America in 1492 and the succeeding period of European colonial expansion that there was any important distribution of cultivated plants as between Eurasia and America and *vice versa*. This fact has a very striking bearing on certain persistent claims that are made over and over again regarding the origins of pre-Columbian civilizations in America, and may be accepted as reasonably good evidence that no ancient contacts between the two continents existed. The early dissemination of cultivated plants within the limits of the eastern or of the western hemisphere is in itself an excellent illustration of diffusion, but a diffusion limited by barriers in the form of broad seas that early civilized man could not pass. Pioneer advanced civilizations, whether in Eurasia or in America, failed to keep pace with the spread of early agriculture even within the limits of the one hemisphere or the other. The botanical, zoological and agricultural evidence is wholly in support of the idea that pre-Columbian civilizations in America were autochthonous, gradually developed here over a period of many centuries, quite as parallel early civilizations were developed in Eurasia, the one having no influence on the other until after the period of European expansion following the Middle Ages.

CULTURE AS A DETERMINANT OF BEHAVIOR

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"Culture as a determinant of human behavior." I read this title as an injunction to prove that there exists a science of human behavior, which is the science of culture. Culture, in fact, is nothing but the organized behavior of man. Man differs from the animals in that he has to rely on an artificially fashioned environment: on implements, weapons, dwellings and man-made means of transport. To produce and to manage this body of artifacts and commodities, he requires knowledge and technique. He depends on the help of his fellow beings. This means that he has to live in organized, well-ordered communities. Of all the animals he alone merits the tripartite title of *homo faber, zoon politikon, homo sapiens.*

All this artificial equipment of man, material, spiritual and social, we call technically culture. It is a large-scale moulding matrix; a gigantic conditioning apparatus. In each generation it produces its type of individual. In each generation it is in turn reshaped by its carriers.

Is this big entity itself subject to laws of a scientific character? I for one have no hesitation in answering this question in the affirmative. Culture is a determinant of human behavior, and culture as a dynamic reality is also subject to determinism. There exist scientific laws of culture.

The possibility of a really scientific approach to humanism and anthropology is still contested. It is not superfluous, therefore, to reaffirm the existence of determinism in the study of human culture.

In my opinion the principal ailment of all humanism is the disjunction of empirical approach from theory, of methods of observation from speculative doctrine. It will be best, therefore, first to turn to the testimony of cultural fact itself. It is easiest to grasp the essence of a phenomenon in contemplating its manifestations through a wide range of variation. Let us then make a rapid flight over the globe and obtain bird's-eye views of some highly divergent types of human culture

Let us descend first on the arid and dusty steppes of Central East Africa, inhabited by the Masai, the famous, fierce warriors of the region. On approaching the native encampment we are met by a group of men, tall, dignified, armed with iron spears and daggers. Their women, svelte and elegant, startle the new-comer with the glitter and rattle of the wrought-iron ornaments encircling their necks, wrists and ankles. Both sexes still wear the native robes of soft goat- or sheep-skin. Not a shred of calico, no European trinkets mars the archaic vision of men and women of Africa as they lead us into the ring of low, brown huts, made of thatch, plastered with cow dung and enclosed with a stout fence of prickly shrub.

Conservative in his material culture, the Masai still clings also to his old tribal ways. He still remains at heart a gentleman robber, herdsman, cattle-lifter and warrior. When, after years of drought, starvation threatens them among their pestilence-stricken herds, how can they help using force in which they have been trained through generations, against their fat and flabby neighbors grown weak in their wealth and security? Their whole social organization—age-grades and military drill, mutilations and tests of endurance—are tuned up to the development of war-like virtues. The Masai warrior, that is, every man between puberty and marriage, lives in a special camp, devoting all his time to the aristocratic arts of doing nothing and preparing for war. He is governed by a democratic régime in which an elected captain administers law and leads the men into battle.

Agriculture they despise, vegetables being food fit only for women As a Masai warrior put it to me in a convincing argument: "The Earth is our Mother. She gives us all the milk we need, and feeds our cattle. It is wrong to cut or scratch her body," a confirmation of the psycho-analysist's conception of Mother Earth, by one who had not studied the works of Professor Freud yet!

As to sex morals, they leave entire freedom to immature girls, who consort with the warriors in their camp At puberty every woman has to undergo a drastic operation, clitoridectomy, which constitutes their marriage rite.

The whole tribe owe allegiance to the *Ol'loibon,* the hereditary rain magician and prophet. He controls them through his gift of divination and his power of producing magical fertility of land and women.

How can we press this strange, exotic material, as rich and varied and elusive as life itself, into a scientific scheme? The temptation to stop at artistic impressionism is great. We might well feel that it would be best to paint the war-like Masai in exaggerated colors in order to bring out the martial, boisterous, licentious "genius" of this culture.

Indeed this type of procedure is the latest fashion in anthropology. Since, however, we are in search of a scientific, that is, deterministic approach, let us inquire into what are the main interests of the natives, the pivotal points of their tribal life. We see at once that their interests center around food, sex, defense and aggression. Divination and prophecy, and their political influence, are related to their military adventures and the vicissitudes of climate. The age-grades are an occupational organization correlated with their military life; they form an educational system in which tribal knowledge is imparted, discipline and endurance inculcated.

Thus culture, as we find it among the Masai, is an apparatus for the satisfaction of the elementary needs of the human organism But under conditions of culture these needs are satisfied by round-about methods. The Masai can not turn to nature directly in order to nourish himself. In the long development of his tribal culture, the institution of pastoralism has come into being. The tending, breeding, exchange and ownership of cattle, incidentally also the need of its defense and protection, impose derived or secondary imperatives on the life of the Masai. The cattle kraal, military camps, seasonal migrations and fertility magic are the outcome and correlates of pastoralism.

The continuity of the race equally does not work by physiological determination alone. Sexual appetite and personal attraction, the urge to mate and the desire for children are reformulated culturally. Each phase of the biological process—maturation, puberty, courtship, marriage and parenthood—is correlated with the mode of life and the arrangements of domesticity and bachelors' camp; and the whole is safeguarded by the military organization. The vast phenomenon of kinship, including the family, marriage, clanship and the laws of descent, is the cultural counterpart of the physiological process of reproduction.

Let us see what the conditions are in a neighboring tribe. Not far from the Masai steppes, on the slopes of the Kilimanjaro, the highest mountain in Africa, live the Chagga, an agricultural, sedentary people. The Chagga, though he also keeps and appreciates cattle, is mainly a tiller of the soil. Yams and pumpkins, peas and millet thrive well on the fertile green fields of the Kilimanjaro. The staple food, however, is the banana. As the Masai culture has been labelled "cattle-complex," so the Chagga culture could certainly be defined as a banana obsession. The Chagga lives on bananas; he lives among bananas—every homestead must be surrounded by its banana grove—and when he is dead he is buried amid bananas.

In contrast to the nomadic Masai, the Chagga have a highly developed body of land laws. Their large-scale system of irrigation is a feat of engineering unparalleled anywhere in native Africa south of the Sahara. Again, unlike the democratic Masai, the Chagga have a well-developed chieftainship. In each district the chief is the supreme judge, the source of law, the military leader and the high priest of tribal ancestor-worship. The centralized power of the Chagga, however, is not based on aggressive militarism. They have a highly developed system of defense, with extensive, well-guarded earthworks along the frontiers and enormous subterranean chambers where men, women and cattle were able to take refuge during a Masai raid.

The Chagga differ from their neighbors, the Masai: they practice agriculture; live in fixed settlements; have a developed system of land tenure; and their religion consists mainly in ancestor-worship. They also resemble the Masai in that they practice female circumcision; they have developed age-grades, and they believe in magic by divination. What is the best way of establishing a common measure for the scientific comparison of differences and also of similarities?

Clearly, again, we must compare their institutions, that is, the organized systems of activities, each correlated with a fundamental need. In both tribes we find that to nutrition there corresponds the economic system; dominated among the Chagga by agriculture, among the Masai by cattle-breeding. In both cultures we should have to analyze the economic system by means of such universally valid concepts as the organization of production, the methods of distribution and the manner in which consumption integrates certain groups of people. Among both we would have to consider the physiological processes of reproduction as it is organized into the domestic institutions. The physiological growth of the individual is in both cases institutionalized into the system of age-grades. Political organization comes into being in the satisfaction of the need for safety, in the case of the Chagga; in the case of the Masai the military organization and the political system are the outcome of a periodic need for predatory economics. In both tribes there are, again, corresponding organizations for the maintenance of internal law and order. The political system, in its military and legal aspect alike, imposes its own discipline, morale, ideals and economic requirements.

The transmission of the cultural heritage from one generation to another brings into being the two educational systems of the Chagga and Masai. In both tribes the earlier stages of training are bound up with domestic life; while later on the initiations into age-grades carries on the education in tribal custom and morality.

From the comparison of the two cultures we reach one of our pivotal generalizations. Every culture must be analyzed into the following aspects: economics, politics, the mechanism of law and custom, education, magic and religion, recreation, traditional knowledge, technology and art. And all human cultures can be compared under the headings of this scheme.

Far from the chaotic, indeterministic

defeatism which overwhelms the amateur, and apparently even some professional anthropologists, this approach gives us a solid scientific foundation.

Incidentally, we also arrive at another conclusion. Anthropology, the science of culture, must study the same subjects as those which confront the student of contemporary civilization or of any other period in human history. It must approach primitive culture from the angle of politics and economics, theory of religion and jurisprudence. And here anthropology may claim a special position among the other sciences of human society and culture.

Its range is the widest; it relies entirely on direct observation, for its sources are in the student's own field It is perhaps the only social science which can easily remain detached from political bias, nationalist prejudice, sentiment or doctrinaire zeal. If this social science fails to develop an entirely dispassionate study of its material, there is not much hope for the other branches of humanism. Hence, in vindicating the scientific character of anthropology we are working at the very foundations of social science. Anthropology has the privilege and the duty of acting as an organizing agency in the comparative study of cultures.

In order to appreciate the influence of environment upon culture, let us leave tropical Africa and move into the desert of snow, ice and rock inhabited by the Esquimaux. Their winter house, made of stone or of snow, has been described as a marvel of engineering, a perfect adaptation to climate and to the available material. It certainly is an example of thorough-going correlation between a material object and the necessities of life. Combining warmth, space and ventilation, it provides during the long winter night comfortable places in which to lie and listen to the long tales of folk-lore, or carry on technical activities. The technological excellence of these natives is also shown in the construction of their sledges and their weapons, of their canoes and of their traps.

In comparison with this, some aspects of their culture seem under-developed. The Esquimaux have been described as devoid of any political system or of legal institutions. They have been often accused of extreme pacifism in that they do not slaughter each other in organized fighting. Yet this is perhaps not quite correct. For though they have no political chieftainship, they recognize the authority of the shaman. He also acts in a roundabout way as an important juridical agency. They have their code of law consisting of many taboos, the breach of which brings down evil not only on the wrong-doer but on the whole community. Tribal calamity can be averted only by public confession. After that the shaman can magically reestablish tribal prosperity. Thus, as the Masai have anticipated psychoanalysis, so the Esquimaux are the forerunners of the Oxford group movement.

On the other hand, towards sex they have the same attitude as the Masai. They have also a somewhat similar type of political system, always with the exception that the one is extremely warlike, and the other has never heard of fighting.

Our approach to a scientific study of culture, through the various aspects which correspond to the fundamental and derived needs of man, does not break down even here: when we apply it to such a one-sided, in many ways stunted, and in other ways hypertrophied, culture as that of the Esquimaux. For the Esquimaux eat and reproduce, maintain themselves secure against weather and animals, have developed means of movement in space, and they also regulate the bodily development of the individual. Their culture consists, like all others, of the cardinal aspects—economics, education, law, politics, magic and religion, knowledge, crafts, art and also recreation.

What about war? Some divisions of the Esquimaux have a minimum of military organization. Others are completely ignorant of fighting Since the polar and central Esquimaux have no neighbors, nor yet any cause for internal quarrels and dissensions, they can not have military institutions This fact confirms our conception of the instrumental nature of organized activities. Where, as in their westernmost offshoots, the Esquimaux are in contact with warlike Indian tribes, they have developed the organization, the virtues and the apparatus of war

In the study of war, as of any other aspect of culture, the strict application of scientific determinism is necessary. This is achieved by clear definitions, empirical concepts and inductive generalization. All the wrangles as to the innate pacifism or aggressiveness of primitive man are based on the use of words without definition. To label all brawling, squabbling, dealing out of black eye or broken jaw, *war*, as is frequently done, leads simply to confusion. One author tells us then that primitive man is a natural pacifist Another has recently described war as indispensable for the survival of the fittest. Yet another maintains that war is the main creative, beneficent and constructive factor in the history of mankind. But war can only be defined as the use of organized force between two politically independent units, in the pursuit of a tribal policy. War in this sense enters fairly late into the development of human societies.

Only with the formation of independent, political units, where military force is maintained as a means of tribal policy, does war contribute through the historical fact of conquest to the building up of cultures and the establishment of states. In my opinion, we have just left this stage of human history behind, and modern warfare has become nothing but an unmitigated disease of civilization.

I have made this brief digression on warfare because it illustrates one side of the scientific or functional method in cultural analysis. This method is often accused of over-emphasizing the perfect integration of all factors within the working whole of culture. This is a misapprehension. The functional method only insists on the fact that all the elements of culture are related to each other; they are not idle survivals or disconnected traits; they function, that is, they are at work It does not pronounce any appreciation or moral comment as to whether this work is good or evil, well or badly adjusted. As in the case of some primitive types of warfare, and certainly of its most recent developments, the instrumental analysis of culture reveals more cogently than dissection into traits the occurrence of catastrophic maladjustments of human society.

To make clear the necessity of an organic and integral treatment of human life let us consider another example. Let us concentrate for a moment on an important object—*the* object of objects, in a way, the material embodiment of the premier institution of mankind, the family. We shall choose our example from yet another ethnographic area and contemplate a pile dwelling in Melanesia.

In sharp contrast to the arid steppes of Central Africa and the Arctic desert of snow, we are surrounded here by a wilderness of water, coral reef and swamp. The main symptom of man's adaptation to his surroundings is a remarkable achievement of primitive architecture, the house on piles. It stands firmly on its foundations of stout tree-trunks driven deep into the muddy bottom of the lagoon. Constructed of strong material cunningly fitted and lashed together, it resists the combined attacks of wind, waves and weather.

To the lagoon dweller such a house is a fortress where he can take refuge and which he can defend. It is a watch-tower from which he can see the approach of suspicious strangers It is also conveniently near to the coast, which he frequently has to visit in order to tend his gardens. The structure of the house is thus determined by the inter-tribal relations of the people, their economic pursuits, by climate and environment.

It can thus be studied only within its natural setting. But after man has invented, constructed and improved his dwelling, and made it into a fortress, an economic asset and a comfortable home, the house then dominates his whole mode of life The outer shell of his domesticity influences the social structure of family and kinship.

Since in my opinion anthropology should begin at home, let me give you an anthropological impression of modern culture and recount a personal experience in which I very poignantly became aware of the power of things over man.

No experience in my exotic wanderings among the Trobrianders and the Chagga, among the Masai and the Pueblo, has ever matched the shock I received in my first contact with American civilization, on my first visit to New York, when I arrived there ten years ago on a fine spring evening and saw the city in its strangeness and exotic beauty. The enormous yet elegant monsters blinking at me through their thousand starry eyes, breathing white steam, giants which crowded in phantastic clusters over the smooth waters of the river, stood before me—the living, dominating realities of this new culture. During my first few days in New York, I could not shake off the feeling that the strange "genius" of this most modern civilization had become incarnate in the skyscraper, the subway and the ferry boat. Large insects in the shape of automobiles crept along the gutter called street or avenue, subordinate but important. Finally, as a fairly insignificant and secondary by-product of the enormous mechanical reality there appeared the microscopic bacteria, called man, sneaking in and out of subway, skyscraper or automobile, performing some useful service to their masters, but otherwise rather insignificant. Modern civilization is a gigantic hypertrophy of material objects, and contemporary man will still have to fight his battle in order to reassert his dominance over the thing.

But what interests us at present is to find the existence of a common measure between the residential part of the skyscraper and snow-house, pile-dwelling and cow-dung hut.

In the material used, in structure, in architecture, in all, that is, which we can call the form of the object, there is hardly one trait in common. But look at the dwelling as a part of an institution. It appears at once that the principles on which each dwelling is integrated into organized human life and becomes the shell of this life are the same throughout humanity. In the pent-house on top of the skyscraper, in the snow-house, in the hovel of cow-dung, in the hut of thatch, we find the same domestic unit, the family, consisting of father, mother and children.

Is the resemblance only superficial? No. Functionally it is not merely a resemblance, but an identity. The group are united by the same task, the essential business of reproducing the race. A universal type of legal charter gives juridical validity to the group. The act of marriage bestows legitimacy on the children; grants the consorts mutual privileges and duties; it defines the domestic work of husband and wife; above all it imposes on them the duty of looking conjointly after the children. Human parents, unlike animals, are not allowed merely to throw up fresh organisms, but they have to introduce fully fledged citizens into the community.

We have found throughout our survey that the food quest and other economic activities leave a deep imprint on the whole culture. This truism, however, must be supplemented by a somewhat fuller appreciation of the place of economics in primitive culture. Let us once more concentrate on a concrete case, the system of agriculture of the Trobriand Islanders in Melanesia. Their whole tribal life is dominated by agriculture. During the season of hard work, men and women practically live in the gardens. Then, while the plants sprout and grow, the women still have to do weeding. The men, on the other hand, devote themselves to other things, fishing and trapping, industries, canoe-building and trading expeditions. One man only, the garden magician, still remains hard at work. He has been in fact from the beginning an organizer of work; directing the allotment of land, and, while ostensibly he was carrying on his rites, in reality he acted as tribal entrepreneur. Even when it comes to the harvest he still has to bless the crops and then perform over the stored produce a type of magic which, by reducing the appetite of the people, makes food last longer.

But agriculture as an economic activity does not end with the harvest. The distribution of the products is an important business which penetrates into all the aspects of tribal life. Tribute has to be given to the chief, and on this tribute his political power is largely based. A quota of food has to be put aside for tribal ceremonies and this finances largely their public and religious activities. Finally, the third stage of the economic process, consumption, presents many interesting aspects in this tribe, as everywhere else. For consumption means not merely eating, but also handling, display, ritual food offerings and, last but not least, sheer waste.

For in the Trobriands the passion for accumulated food is so great that people prefer to keep their yams till they rot in the storehouses rather than to see the latter empty.

We see then that agriculture must be studied within the context of the whole economic system. For the vegetables are exchanged for fish; they are used in the financing of enterprise and for feeding the craftsmen; for the capitalization of industries. This is especially interesting in the study of the large native jewelry, or more correctly tokens of wealth, which play a considerable part in the political system and which are also ceremonially exchanged in the course of large intertribal expeditions, which are practiced throughout this region. Could we apply the same detailed study to Masai or to Chagga economics, or those of the Esquimaux or Plains Indians, we would see that they also must be considered under the three headings of production, distribution and consumption.

The anthropologist is often asked by elderly ladies or young girls: "Is primitive man an individualist or communist? I want to know that, because I want to know whether human nature is communistic or not." I could refer to one or two instances where a scholar of high repute has played into the hands of the lady questioner, old or young. As a matter of fact, the anthropologist can give an opinion, but only as to the workings of the institution of property and not as to that vague entity, human nature. Communism as public control of private property has always existed and must be present in every culture, simple and developed. Communism, as absence of individual property, does not exist under primitive conditions.

Take the prototype of all wealth, value and property; soil used for agriculture. Complete communism of land actually under cultivation is never found in any primitive society. Production is a process in which man invests labor and intelligent foresight, and at least as much of his wealth as is necessary for planting, and for keeping himself alive while he works. No free human being will do it permanently without some legal guarantee, safeguarding for him the results of his efforts. The guarantee given to each free individual that the results of his efforts will be his to use or to give, is tantamount to individual ownership. Where there are slaves, pawns or serfs, there may be a class of people who work without any claims to the fruits of their labor. But such communism turns men into slaves, serfs or pawns. May this not be true of all forms of communism?

Take again profit. We are often told that with the abolition of private profit all evils, such as war, sexual jealousy, poverty and even drunkenness, will disappear. To me the Marxian doctrine of profit entails a complete misconception of the relationship between the economic factor and other motives and drives in human society. The pocket is not the only channel by which wealth can be maldistributed and abuses canalized. Vanity, doctrinaire zeal, incompetence, personal ambition cause as much havoc as does greed. The men who control production—in Africa or Europe, in Melanesia or America—do not and can not fill their pockets or bellies with gold. Where they can and do harm is in mishandling and misusing the production and distribution of wealth. In order to prevent that, public control by disinterested agencies is necessary. And here it is obviously better to have a system in which control of wealth, legislation and the executive use of power are not concentrated in the same hands, but vested in separate agencies. The totalitarian state and the African autocracy are not models of sound economic systems. The real advance lies in the gradual piecemeal reform, involving all the parts of the economic and political organism. An integral revolution destroys, but it does not create. The concentration of all controls in the same hands means the abolition of all control.

How can we link up religion, magic, sorcery and divination as cultural phenomena with our whole system of interpretation in which we conceive of culture as the vast apparatus for the satisfaction of human needs? We have seen that the fundamental needs of the human organism, those of food, reproduction, safety, freedom of movement, are satisfied under culture by *ad hoc* systems of organized activities. Culture thus establishes the quest for food and the industries, technical constructiveness, courtship and marriage, kinship schemes and military organizations.

We have seen how this cultural roundabout way of indirect satisfaction imposes secondary or derived needs. These are not innate drives of the organism but highly derived implications of man's cultural response to innate urges. Thus economic desires, values, standards, legal inhibitions and the consciousness of one's rights and privileges, social ambition and kinship sentiments, political prestige and submissiveness are essentially human characteristics. But they are imposed by the circumstances of human existence in organized communities and not by reflex or instinct or any factor of innate endowment.

But this is not the end. The vast machinery of culture is maintained, regulated and preserved by the body of traditional lore. This is made possible by language, which allows man to formulate general rules and condense them into concepts. Thus, to systems of action there correspond systems of thought. Action must be based on foresight and on the grip of the context. Man deals with nature and his fellow beings by constructive and imaginative handling of each situation. He has to lay down the results of past experience into systems, fixed, standardized, yet withal plastic. These he hands over from generation to generation.

Systems of human knowledge exist even among the lowest primitives. They must have existed from the very beginning of humanity. The wide-spread misconception that primitive man has no rudiments of science, that he lives in a hazy, mystical or infantile world have to be rejected in the light of our fuller knowledge of primitive cultures.

But though knowledge is easily accounted for, what are the natural foundations of religion and magic? That which establishes man's final superiority over the animals, his power of symbolic and constructive thought, imposes on him also great burdens. It reveals to him the fundamental uncertainty and limitation of his own existence. In order to think clearly man has to look back and remember; he has to look forward and foresee; and that means he is subject to fear as well as to hope. Man, of all the animals, can not live in the present; he can not lead a hand-to-mouth existence from moment to moment. This must finally bring him to ponder on topics where emotions blend with cold reason and where the answer is dictated by emotions, though it is largely framed by reason

What is the ultimate destiny of man and of mankind? What is the meaning of life and the relations between man and the universe? Whence have we come and whither are we bound, and what is the sense of all man's fears, sufferings and disappointments? Metaphysics and religious speculation are as old as knowledge and as old as language itself. At the beginning they are extremely simple and crude. Animism and beliefs in magical force, phantasies about sorcery, ghosts, vampires and totemism, that is, the belief in the spiritual affinity between man and nature, are the answers of primitive man to the fundamental riddles of life. Once we realize their real nature it is easy to perceive their great value. They are well adapted to the limited conditions in which primitives have to live, they contain the answer to the questions of whence and whither, and above all they supply man with ritual means of getting in touch with spiritual forces, of establishing communion with ancestral spirits, totemic beings or divinities, and they allow man to secure his immortality, and thus to give sense to his life.

Knowledge, magic and religion are the highest, the most derived imperatives of human culture Indirectly and through several relays they also are the outcome of man's organic needs. The craving for religion and for magical power, as well as scientific curiosity, are not instinctive. They are the outcome and the correlate of that intelligent adjustment of man to his environment which makes him the master thereof. Magic and, to a much higher degree, religion are the indispensable moral forces in every human culture Grown out as they are of the necessity to remove internal conflict in the individual and to organize the community, they become the essential factors of spiritual and social integration They deal with problems which affect all members of the community alike. They lead to actions on which depends the welfare of one and all. Religion and, to a lesser extent, magic thus become the very foundations of culture.

By now, I trust we all realize that there exist laws of cultural process, and that their discovery is the main task of scientific anthropology.

Our plea for scientific anthropology, of course, is not tantamount to an indictment or exorcism of all the attractive and amusing speculations. Evolutionary aperçus, indeed, I regard as indispensable. Careful and sober diffusionist hypotheses seem to me quite profitable. To minimize or discard a really human interest in humanism would be a crime. To mix up or confuse the emotional or artistic approach with the scientific is a serious lack of judgment. The two approaches must be used simultaneously: They have to complement each other. But science must furnish the foundation.

The scientific theory of culture has also brought to light some really vital truths.

Is the recognition of the universal stability and permanence of the family and marriage of no interest in these days when domestic institutions seem to be threatened on every side? The anthropologist might almost add: "As it was in the beginning, is now and ever shall be." That Communism can not be a panacea for all our cultural troubles may also be an interesting appreciation. We have seen that Communism alone is never to be found in any culture, however primitive or complex. We have seen, also, why Communism as an economic system can not work except in conjunction with slavery. On the other hand, pure individualism does not exist anywhere either. So that some admixture of Communism, that is, public control, has always worked and worked well But it can not work wonders or cure all evils We have defined the rôle of the supernatural as an integrating and organizing force in society. One of the implications of our analysis was that the abuse of law and political power must always lead to cultural disaster. Science and virtue, efficiency and endurance, courage and chastity can never be dictated by edicts nor inflamed by oratory nor yet forced into existence by a system of police spies and police brutalities To replace religion and morality by the secret service of a totalitarian state is a disease of culture.

For we have fully acknowledged the existence of cultural maladjustment and even of lethal ailments of civilization. The very concepts of adaptation and function imply degrees and qualifications, from excellence to decay.

Our present civilization is undoubtedly passing through a very severe, perhaps a critical, stage of maladjustment. The abuse of legal and administrative power; the inability to create lasting conditions of peace; the recrudescence of aggressive militarism and magical trickery; the torpor of true religion and the assumption of a religious garb by doctrines of racial or national superiority or the gospel of Marx—all this shows that, while we have become the masters of inanimate nature, we have connived at the complete enslavement of man by machine.

The greatest need of to-day is to establish a balance between the stupendous power of natural science and its applications and the self-inflicted backwardness of social science and the consequent impotence of social engineering To repeat a truism just mentioned, we have allowed the machine to overpower man. One of the reasons of this is that we have learned to understand, hence to respect and to handle the mechanism But we have failed to develop the really scientific spirit in humanism.

To-day the freedom to exercise purely scientific determinism is threatened in many countries. This freedom is even more essential for social than for natural science. It is, therefore, our duty on this occasion to insist on the necessity for this freedom. We are assembled here to celebrate the Tercentenary of one of the greatest workshops of science and reason ever established by man The founding of Harvard was an act of human behavior not outside reason and determinism It was determined by wise foresight, and its existence and work have been enduring factors in developing reason and determining rational behavior. Harvard has always fostered that spirit of science which means freedom in the search for truth, for the laws of nature and of human behavior. Let this spirit preside over the development of the comparative science of man and we may yet hope that the spirit of Harvard, that is, the spirit of science, will prevail in the conduct of human affairs.

INTELLIGENCE AND THE GUIDANCE OF ECONOMIC EVOLUTION

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IN the confident days of its youth, political economy believed that it had solved the important and timely problem put before this session. It was ready to dispense advice on public policies, and its admonitions concerning the duties of the state toward economic enterprise were especially clear and urgent. Current economics, the offspring of this authoritative discipline, is a more cautious creature. When asked for practical advice it reveals an inferiority complex; but in compensation it claims to have a stricter scientific conscience than troubled its philosophic forebear. Economic theory now seldom forgets that its conclusions rest upon assumptions expressly designed to simplify its problems sufficiently to make them amendable to analysis. When asked for advice it answers primly: "That is not a proper request to make of a science. My task is merely to examine the functional relations among certain processes under a variety of carefully specified conditions. What I have to say is the truth and nothing but the truth; it is not the whole truth. In practical affairs," economics goes on, "it is necessary to take account of many factors that I purposely exclude. You should indeed pay heed to my findings, they are highly important. But you should not expect me to tell you what to do in this messy world, so unlike the orderly realm I create for scientific ends. If some of my alleged representatives desire to dictate your policies, don't suppose that they speak with my authority. Of course an economist is also a citizen, and like his fellows must reach decisions on current issues of all sorts; but if he remembers what I have taught him he won't try to pass off his notions about policy as my deliverances. You do well to seek scientific understanding as a basis for action; but please note that I have several sister sciences of human behavior whose business it is to study the numerous factors that I pass over. You should consult the whole family, though I am sorry to say that my younger sisters are so immature that you can not expect much help from them." On which ungracious note, economics resumes the irreproachable attitude it has learned to strike when asked to make itself useful.

Needless to say, the planners of this Symposium on "Authority and the Individual" would not express themselves in this wise. They have proposed collaboration among the social sciences and humanities "with a view to breaking down traditionally specialized lines of approach to an important and timely problem and to make its solution the object of a common attack." My whimsical version of the methodological position of current economics indicates that its votaries are logically bound to accept this program. For us in particular collaboration should be a wholesome experience, for it should correct our attitude toward the other social sciences and put us in our proper place. The "purer" we make economics the more generously must our findings be supplemented before they can be relied upon as a trustworthy guide, and the keener should we be to work with men of other disciplines.

But collaboration may take two courses. First, representatives of different disciplines may bring each his own contribution to the understanding of a problem in as perfect a form as his technique makes possible, leaving to others the responsibility of fitting together the several contributions. Conscientious specialists who realize how likely they are to go wrong when they wander outside their familiar boundaries may well prefer this course. But who can vouch that the several contributions worked out by independent specialists will make a whole? And what group is ready to assume the difficult and responsible task of putting the results together so far as they will fit? If there is no such group at present, can one be formed? That is a question for the future and I shall come back to it later. But as matters now stand, can not the representatives of the social sciences and humanities collaborate with one another in a more direct fashion? If we wish to break down our traditionally specialized lines of approach and join in a common attack upon social problems, must not each of us strive to effect some such change in his own thinking? This second mode of collaboration involves not merely following one another's work but also making use of one another's approaches to our own problems. It is a difficult course and beset by dangers; yet in so far as we can pursue it each of us can make his work as a specialist more interesting to himself, more valuable to his colleagues in other sciences and more effective in a common attack upon the problems we hope to solve.

Believing that we should construe in this sense the invitation of Harvard University to collaborate with one another, I shall discuss the formidable topic assigned to me, "Intelligence and the Guidance of Economic Evolution," not as a problem in pure economics but as realistically as I can, making use of what notions I possess about human behavior at large. Doubtless I shall make mistakes that economic historians, psychologists, sociologists or political scientists would avoid. And I know that some men of my own craft will think my whole procedure ill-advised. But genuine efforts at collaboration involve such risks, and each of us is justified in running them.

Let me start with the solution of the problem set before me that was given by Adam Smith in 1776. His "Wealth of Nations" was devoted in large part to criticizing the mercantilist doctrine that it is the statesman's duty to regulate the economic activities of private people as much as it is his duty to provide for the common defense. Adam Smith's critique centered on the proposition that the wealth of a nation is the aggregate of the wealth of its citizens, and that each citizen in his local situation is a better judge of how to augment his wealth than a distant statesman can be. Restated in terms of my topic, this argument runs: Nations prosper more when they leave the guidance of their economic evolution to individuals than when governments attempt to guide. No distrust of intelligence as a guide is implied; the contention is that in the industrial army planning by a central staff is worse than futile; the planning should be done by the private soldiers, individually or in such companies as they voluntarily form under captains who rise from the ranks. All that the staff need do for industry is to see that the privates and officers treat one another fairly, and to perform a few necessary tasks that no private or company would find it profitable to undertake.

Had this symposium been held on the hundredth anniversary of the "Wealth of Nations," I fancy that the economists invited to participate in it would have felt competent to treat this problem without the collaboration of authorities in the other social sciences. And they would have endorsed Adam Smith's solution of the problem, some with more, perhaps some with less reservations than the Father of Political Economy had made. It is true that the last of the great classical trinity, John Stuart Mill, had avowed himself a Socialist; but he built his temperate hopes for the betterment of economic conditions, not upon a recrudescence of governmental planning, but primarily upon the cumulative growth of producers' cooperation. Gradually the employees of business enterprises would take over the functions of ownership and management; for workers expecting a share in the profits would be more industrious and more intelligent than mere wage-earners, and so cooperative concerns would prevail in the competitive struggle for survival. Of course this speculation posits the continuance of what Adam Smith fondly called "the obvious and simple system of natural liberty" Since the most respected Socialist of the time accepted the general principle of *laissez-faire* that doctrine seemed secure.

But 1876 marks as well as any date we could select the culmination of faith in the guidance of economic evolution by individual intelligence To-day the problem that Adam Smith thought he had solved is as timely as it was in 1776. I doubt whether any economist attending the present symposium feels as competent as Adam Smith did to tell governments just how far they should carry their intervention in economic activities For within the past one hundred and sixty years economists have made progress toward grasping the complexities of social problems, if not toward agreement upon solutions. Numerous developments have combined to change their attitude toward governmental regulation of economic enterprise, of which the most important has been the world's experiences with different types of economic organization.

Great Britain was far better prepared than Adam Smith realized to accept his teaching. Private enterprise, often in defiance of mercantilist regulations, had become a mass phenomenon before the "Wealth of Nations" was published. The new doctrine was a philosopher's rationalization of practices engaged in by enterprising men because they were profitable Negatively it eased the consciences of technical law-breakers by assuring them that their actions promoted the public welfare; constructively it gave them a logical argument for demanding the repeal of hampering regulations. Of course, beneficiaries of the old system were not deterred by any theorizing from striving to maintain their legal rights But technical developments that Adam Smith could not foresee kept weakening the defenders of the old order, swelling the number and increasing the power of those who profited by *laissez-faire.* A growing volume of trade, domestic and foreign, stimulated men with initiative to try new forms of business organization, some of which proved highly efficient. The same factor created a lively interest in finding cheaper methods of producing, processing and transporting materials in bulk. This alliance of mechanical invention and business enterprise proved irresistible. The classes that had vested interests in the old order could neither meet the commercial competition of their rivals who were introducing new methods nor make effective answer to Adam Smith's logic. Statesmen of a speculative turn of mind readily accepted the "Wealth of Nations" as their guide in commercial policy; statesmen who waited for the teachings of experience followed more hesitantly but in increasing number; politicians who accepted the dominant opinion of the day slowly fell into line. Partly by allowing mercantilist statutes to become dead letters, partly by formal action, the country dropped the policy of mercantilist planning and deemed the results good on the whole. By the 1860's or 70's most Britons who thought about such matters believed that practical experience had demonstrated the soundness of Adam Smith's doctrine and that other countries would gradually learn the great lesson that theory and practice combined to teach. A glowing vision was cherished by liberal spirits of freedom for all men in their economic, political and social relations, a vision of peace among the nations securely based upon recognition that peace is the best policy, a vision of cumulative progress in the conquest of nature assuring not merely a higher standard of comfort for all mankind but also a nobler life. What Carlyle had dubbed the "dismal science" appeared to many as the brightest hope of the race.

II

But decades before this stage was reached, certain emendations had proved necessary in "the obvious and simple system of natural liberty" as presented by Adam Smith. The horrible treatment of "pauper apprentices" in some cotton mills and of climbing boys apprenticed to chimney sweeps early convinced the public that these unfortunate children were not able to judge or to defend their own interests. They seemed to need and they were granted the protection of the state. Later revelations of the exploitation of child workers at large, of young persons and also of women led to further protective legislation justified by the same argument. Only adult males were credited with knowing better than Parliament what was good for them and with being able to look out for themselves. But even that amended proposition was challenged with success. Seamen would sail on overloaded ships, colliers would go down ill-ventilated mines, factory hands would take foolish risks with unfenced machinery, men would expose themselves to occupational diseases. Indeed the new industry, imperfectly controlling the powerful natural forces it was putting to work, was full of hazards that men underrated, and government felt constrained to exercise its superior intelligence for their benefit. It appeared also that many investors were quite incapable of judging where to place their capital safely, that consumers would buy impure foods and drugs, that town dwellers endangered one another by their ignorance of sanitation. In short, the assumption that the individual is a better judge of his own interests than a distant statesman was found to be subject to many exceptions. These exceptions became more numerous and more important as social organization became more complex. Hence governmental intervention was gradually extended in many directions of which Adam Smith had not thought, but of which perhaps he would have approved could he have revisited Great Britain in 1876.

Interwoven with the problems presented by those who seemed not to know their own interests was a cognate problem presented by persons who claimed that they could not protect interests of which they were painfully conscious. The argument for *laissez-faire* assumed that in pursuing his own interest every individual would be prevented from charging unduly high prices for his goods or services by the competition of rival sellers and also protected against having to accept unduly low prices by competition among buyers This competitive régime promised to work out a rough sort of justice and also to stimulate efficiency in serving the public. Business men who did not measure up to current standards would be reduced to the status of workmen, taking orders from abler captains of industry. Thus inefficiency would be penalized, merit rewarded and the country assured that its economic energies were directed by the ablest available leaders—the ablest because they were continually being subjected to the infallible test of ability to survive in a competitive struggle. It is no wonder that this view captivated many philosophic minds and suited successful men of affairs; nor is it any wonder that other classes were less satisfied. Wage-earners in particular protested that the conditions of the labor market did not assure them a fair price for their services. For in this market the sellers were a crowd of individuals ill informed about current conditions and future prospects, unskilled in bargaining, forced by pressing need to underbid one another. On the other side of the market stood the employers, each one a combination in himself, able to merge into larger combinations when they saw fit, the best judges of commercial conditions, keen bargainers, able to wait. How valid was this distressful picture of the workingman's plight in the early decades of the nineteenth century admitted of argument. The point that concerns us is that disciples of Adam Smith persuaded Parliaments that were moving toward *laissez-faire* to repeal the Anti-Combination Acts and to legalize trade unions. Some advocates of these measures believed that wage-earners would learn that combinations were expensive and futile, but they were bad prophets. Trade unions grew in strength after the fluctuating fashion of human institutions, and later Parliaments confirmed the policy of countenancing voluntary restriction of competition among sellers in the labor market.

Meanwhile cases were becoming prominent in which competition among business enterprises themselves seemed plainly detrimental to the public interest. The classic illustration was provided by the gas industry. If two competing companies sought to serve the same town each would have to lay mains and provide connections. The total investment would be needlessly large. If both companies received the going rate of return upon their capital the consumers would be overcharged. If neither company made money, or if one succeeded and the other failed, part of the country's precious capital would be wasted. Thus what were often called "natural monopolies" seemed to be exceptions to the rule that prices would be kept reasonable by competition. They were also recognized as exceptions to the rule that government should let business alone. For the only way to protect the customers of monopolies from extortion seemed to be governmental regulation of rates or governmental ownership. British municipalities that were strongholds of *laissez-faire* became strongholds also of "municipal socialism," while the central government experimented with various plans for controlling the railways and took the telegraph and telephone systems into the post office.

The continued progress of the industrial revolution and the concomitant development of large-scale business kept raising new problems of this type. Were all public utilities best treated as monopolies and subjected to special controls? Should the production of electrical current, perhaps coal mining and even housing be added to the list of public utilities? Was not the progress of engineering with its trend toward more elaborate and specialized machinery threatening to put many industries into a position where cut-throat competition among independent corners would be almost as wasteful as competition between two gas companies? And if business managers stopped short of cut-throat competition, how far short would they stop? Left to themselves, would they compete actively enough to protect consumers?

The theoretical difficulty underlying this practical danger had been pointed out by Adam Smith's younger contemporary, the Earl of Lauderdale, who challenged the assumption that the wealth of a nation is the aggregate of the wealth of its citizens. On the contrary, said Lauderdale, public wealth consists in an abundance of useful goods, while scarcity enhances the value of private property. The individual pursuing his own gain seeks to limit his output to the volume most profitable to himself, and that aim is antagonistic to the public's interest in abundance. Where active competition prevails, the individual who seeks to increase his profits by limiting the supply will lose customers to his rivals; there the pursuit of self-interest leads every producer to sell as much as he can so long as prices exceed his cost of production. But this "artificial harmony of interests" established by competition is precarious. For the pursuit of self-interest gives every man a strong incentive to escape from the pressure of competition into the ampler freedom of monopoly; that is, to destroy the one great safeguard of the public's interest in abundance. Every class engages in this destructive practice so far as it can, and blames other classes that succeed in so doing. Employers charge that labor unions limit the number of apprentices, working hours and output per man-hour; that they seek to limit employment to union members, and limit admission to their own ranks by high initiation fees. Business men are popularly assumed to be the most successful sinners. Thorstein Veblen could picture the modern captain of industry as a strategist concerned mainly with the practice of "capitalistic sabotage"; that is, with the effort to limit the inordinate abundance of goods that modern engineering would provide to those modest supplies that will yield the maximum net revenues.

Another type of difficulty, business interference in government, had been pointed out by Adam Smith himself. In his eloquent plea for "the simple and obvious system of natural liberty," Smith tacitly assumed that government aimed to increase the wealth of the nation as a whole. But in a much earlier passage, not often recalled by his disciples, he had pointed out how unscrupulously clever are men of business in persuading the government that measures profitable only to their selfish interests will be advantageous to the public. A wise administration would be suspicious of advice from that quarter. Of course the laboring classes were too ignorant to form opinions upon public policy; but the country gentlemen might be trusted, for though often stupid about commercial matters their interests coincided broadly with those of the nation. Ricardo reversed this dictum: the interests of the landlords were opposed to those of every other class in the community, and a government controlled by them was selfishly misused to restrict foreign competition in foodstuffs in order to keep up rents—a policy that made food dear and money wages high, thereby reducing profits and impeding the accumulation of capital, on which progress depended. Later generations found reason for believing both Smith and Ricardo, or rather for believing that every class, the wage-earners included when they attain political influence, is eager to use the power of government for selfish ends. If any class has a bad eminence in this respect it is because circumstances enable that class to exercise more pressure upon government for the time being. And the more developments of one sort or another forced government to concern itself with economic affairs, the more private parties strove to control government. This development attracted more attention in the United States than in Great Britain; but it is naïve to think that in any country the problem of the state and economic enterprise can be treated realistically without considering economic enterprise in politics. We economists have been so prone to chide governments for interfering in business that we have often overlooked the extent to which these interferences are dictated by particular groups of business men. We usually think of government as Adam Smith did when he was expounding the policy of *laissez-faire,* forgetting what we know of politics, just as Adam Smith for the moment forgot his warnings about the machinations of the commercial interest.

III

Not only did private enterprise produce various unfortunate results, it also failed to produce some good results that were expected by its champions. One bitter disappointment came in international relations. As noted before, during the heyday of *laissez-faire* it was predicted that the mutual gains from free trade, demonstrated so convincingly by political economy, would bind the peoples of the world in an economic league of peace. Unhappily that was not the outcome The volume of international trade did increase enormously as applications of science reduced the costs of transportation. But even the great commercial nations did not raise their foreign policies to the level of enlightened self-interest They continued as in the age of mercantilism to waste their economic energies and to prostitute their intelligence in waging intermittent wars, though all sensible men knew that the chief outcome of wars is mutual impoverishment and frustration. Competition among the nations for economic gains kept degenerating into wrangles and wrangles into fights—as would competition among individuals if there were no authority in the background to enforce peace. The economic theorists of *laissez-faire* had committed a sin of omission that John R. Commons is helping this generation tardily to repair. They had failed to realize the implications of the rôle played by courts in economic transactions Where there is no court to decide disputes, backed by power to enforce its decisions, enlightened self-interest has but a feeble control over human passions.

Nor was that the whole or the worst of the psychological error. Even in individual dealings regulated by courts, enlightened self-interest did not dominate behavior so much as the logic of *laissez-faire* required. The most disconcerting discovery, or rather rediscovery, made by the social sciences in the nineteenth century was that man is a less rational animal than he thinks himself He is prone to commit the "intellectualist fallacy" in giving accounts of his own behavior; that is one of his subtle ways of maintaining his self-esteem. Systematic thinkers are especially subject to this fallacy because the easiest way to give an intelligible account of what men do is to suppose that they are guided by calculations that the theorizer can repeat and foretell. Thus, as Walter Bagehot happily remarked, Adam Smith tacitly assumed that "there is a Scotsman inside every man." The literal-minded closet philosopher, Jeremy Bentham, made the assumption explicit. He crystallized the conception of functional psychology current among British thinkers of his time in the "felicific calculus"—a scheme so congenial to minds formed by a money-making age that diluted versions of it still dominate many of our speculations about economic behavior. Even the Malthusian "principle of population," with its modern-sounding emphasis upon instincts and habits, could be interpreted in terms of the felicific calculus by disciples of Bentham. The working classes, like their betters, were controlled by the two sovereign masters, pain and pleasure: but their lamentably defective education prevented them from foreseeing the pains that large families would bring upon them. The obvious remedy was to teach these unfortunates to associate low wages with premature marriages. Thus political economy had a great civilizing mission to perform for the most wretched part of humanity as well as for the more fortunate; it should help all mankind to calculate correctly, that is, to find the real way of maximizing net pleasures. But Darwin's teaching that man is an animal fundamentally ruled by instincts changed the perspective in which the social sciences saw problems of human behavior. Psychologists revealed the artificiality of the hedonistic analysis. Thinking appeared to be at best an intermittent process, concerned with the humble task of finding ways toward ends set by more fundamental forces, and engaged in typically when routine modes of action encounter obstacles. Bentham's clarity gave way to confusion. Men are moved by fears and angers, vanity and curiosity, longings for adventure and longings for security, sympathy with others and delight in making invidious comparisons to their own advantage, by obsessions, prejudices, visions, by forces conscious and unconscious to which we give a hundred names but can not delimit, describe and classify in any way on which we can agree.

The rediscovery of man's irrationality helps us to understand why Adam Smith's "obvious and simple system of natural liberty" was never given a full trial. Perhaps a race evenly endowed with enlightened self-interest might have made an earthly paradise of the sort they would have liked by practicing *laissez-faire.* Certainly the very unevenly endowed men that populate this planet, shortsighted, quarrelsome, sentimental, did not do so. When individual enterprise produced results they did not like they would not wait for the evils to correct themselves in the long run Each generation has realized the force of Mr. Keynes's remark that in the long run we shall all be dead Nor do all economic evils tend to cure themselves; human nature being what it is, there are social processes of degeneration that work cumulatively. The actual outcome was a mixed system of control by the imperfect intelligence of individuals and control by the imperfect intelligence of governments And toward the end of the nineteenth century the factor of governmental control was gaining ground even in Great Britain. Just as individual enterprise had become a mass phenomenon in a nation that accepted mercantilism in principle, so governmental planning was becoming a mass phenomenon within a nation that accepted the principle of *laissez-faire.*

IV

While dwelling upon the difficulties encountered as the system of free enterprise enfolded, we should not forget how that form of economic organization stimulated men to apply scientific discoveries to the work of the world, how industry in turn aided scientific research, how standards of living rose, death rates declined and population increased, how the Europeans spread over the earth exploiting natural resources and backward peoples, or how mightily the leading commercial nations gained in power and prestige. Those are high lights in the dazzling picture of progress in the nineteenth century, as seen by people of our culture. But the economic progress, so powerfully promoted by individualism, produced consequences that led the successful nations to tinker further with their economic organization. If the earlier stages in the resurgence of national economic planning were due primarily to incidental defects in the workings of *laissez-faire,* the later stages were due primarily to results produced by the major successes of that system

The growing economic prosperity of the nineteenth century pushed men closer together while it also widened the areas from which they drew supplies and over which they marketed products. Increasing density of population makes what one man does more important in numberless ways to the health and happiness of his neighbors Men feel the need of more common rules concerning what no one shall do and also concerning more things that everyone must do for the commonweal Government is the great agency for setting minimum standards of conduct that must be enforced upon the recalcitrant, and so finds its functions multiplying as the interdependence of individuals becomes more intimate and intricate So also the wider geographic scope of economic organization exposes the modern man to more and more hazards that he cannot control, and he calls stridently upon his government for aid. Local regulations that served well enough in an earlier day are replaced by national rules, supplemented by international conventions.

This trend appears most clearly in American experience. "Rugged individualism" flourished upon the frontier. Laws were of slight help to the trapper and the squatter; they wanted little from the government But the farmers who followed soon began demanding that the government aid them in getting facilities for shipping their produce to market; when these facilities had been provided they demanded that government regulate railroad rates; that government provide "cheap money"; later that government make grants to improve roads, set up land banks, subsidize exports of surplus produce, extend protective duties to agriculture, and so on. When we tell the story of American prosperity we stress the westward expansion as one of the brightest episodes and celebrate the sturdy enterprise of the pioneers that made it possible. But when we study the record in detail, we find the conquerors of the continent full of complaints concerning their economic plight, and insistent with the full force of their rugged personalities that government come to their aid.

In other ways also the prosperity of the nineteenth century turned men's minds toward governmental planning. The extraordinary increase in the physical volume of production made unprecedented inroads upon the resources provided by nature. So far as I know Stanley Jevons was the first economist to call attention to this feature. In the 1860's he showed that British industry and commerce rested on a foundation of cheap coal, and that if the extraction of coal continued to grow as rapidly in the future as it had been growing in the recent past the commercially accessible deposits would be exhausted in no long time. Mineral deposits were irreplaceable by man, and the race might wreck its career by looting mother nature's cupboard. Even abundantly endowed America took alarm over the destruction of its timber resources, the drain on its reserves of anthracite, the waste of its natural gas and petroleum, and, most menacing of all in the long run, the depletion of its soils through reckless cropping and erosion. The time span taken into account by individual enterprises was but as a day in the life of a nation. In manufacturing, transportation, commerce and finance this difference might give rise to no grave troubles; but in the extractive industries a few generations of ruthless individuals might destroy the nation's heritage to get a mess of pottage for themselves. To prevent that irremediable disaster the conservationists saw no other remedy than governmental regulation based upon long-range planning.

Finally, the more completely any country organized its economic life on the basis of making and spending money incomes, the more effectively it developed its natural resources, but the more did it suffer from recurrent business depressions. It seemed that the equilibrium among economic activities directed toward the making of profits was essentially unstable. Periods of rapid expansion never lasted more than three or four years. Some parts of the economic mechanism always expanded faster than others, and when the resulting stresses exceeded the limit of tolerance prosperity ended in a crisis followed by a period of contraction, from which business recovered only to repeat the same disillusioning round. Men learned some devices for mitigating the violence of crises and alleviating the sufferings of depression; there were times when some nations fondly believed that they had mastered the disease; but further experience corrected that optimistic error. And these rhythmical alternations in the fortunes of commercial nations produced cyclical fluctuations about the secular trends of *laissez-faire* and of governmental planning. During the prosperous phases of business cycles men were minded to demand that government let business alone; during depressions they demanded governmental interventions of the most diverse kinds. In this way also governments have been led to assume heavier responsibilities for stimulating, repressing and supplementing private enterprise.

Another concomitant of economic progress that caused grave apprehension in many minds was the increasing disparity in the size of individual fortunes and in the magnitude of business enterprises. The poor did not grow poorer, but the rich certainly grew richer. The one-man business did not disappear, but the billion-dollar corporation came into existence. Those who feared these trends invoked governmental action to moderate them. Inheritance taxes, steeply-progressive income taxes and anti-trust legislation of numerous sorts were in large part efforts to check the inequalities in economic success which a system of individual enterprise breeds.

No other people had gone so far as the British toward accepting the doctrine of *laissez-faire,* and, to the best of my knowledge, in no other country was the reversal of the trend in the latter part of the nineteenth century so clear. But a change of the same type can be discerned in the economic speculation and the practical policy of various other nations, among them the United States.

From the outset, American policy had been an unstable mixture of national planning and reliance on the play of private enterprise. The severing of relations with Great Britain forced our ancestors to devise a formal plan for governing themselves. When their first plan, the Articles of Confederation, had proved itself inefficient, they drew a second plan providing for a stronger central government, and that worked better. The first Secretary of the Treasury under the Constitution plunged at once into national economic planning and scored a series of notable successes. Among other measures he induced Congress to adopt a mild protective tariff to stimulate domestic manufactures. After decades of acrimonious struggles over this issue, we built a high wall of tariffs around our borders, while practicing free trade within them. The more powerful our industries grew the higher the duties rose; for this is one form of government planning that was guided substantially by private enterprise itself. Early in our history we sought to develop a national transportation system of highways and waterways; later we put our trust in privately owned railroads, to which we made lavish grants of public lands; later still we subjected the railroads to a complex set of state and federal regulations. We devised plans that promoted the settlement of the public domain by independent farmers, and allowed our timber and mineral lands to be plundered in wasteful fashion. First as farmers clearing fields for the plow, then as lumbermen supplying a market, we slaughtered our forests; now perhaps the most carefully devised of our national plans aims to conserve what remains of our timber resources. For decades we complacently watched the tide of immigration rise; then we began excluding those whom we held to be undesirable aliens; recently we have adopted a systematic plan for limiting the number and supposedly improving the quality of those whom we admit. We lagged behind European countries in social legislation and in governmental ownership of public utilities, but we led in efforts to check the growth of monopolies and to compel business men to compete with one another. We have evinced a childlike faith in what we can accomplish by passing laws and a childlike vanity in our sturdy individualism. But more and more our individualism has expressed itself in efforts to use the government as an agency for attaining what we severally desire.

This secular trend toward bolder and more varied economic planning by governments that prevailed in the western world during the closing decades of the nineteenth and the opening decade of the twentieth century was suddenly and enormously stimulated by the world war. Each of the belligerents felt compelled to mobilize its economic resources in order to maximize its military efficiency. Governments endeavored to control production and consumption, imports and exports, railroads and shipping, employment and investment, prices and finances. Vexatious as these schemes were felt to be, they were approved by the citizens at large as essential to success. No combatant dared trust to the free play of individual enterprise when threatened by invasion.

Though most of the governmental controls were released more or less promptly after the return of peace, there has been no such trend toward *laissez-faire* as followed the Napoleonic wars The collapse of the Czarist régime in Russia under the stress of war made it possible for a Communist party to seize control and initiate the most ambitious experiment in national planning ever tried by a great country Italy has accepted Fascism and its plan of a "corporative state" Germany has entrusted her fortunes to a party that is trying to remold both the economic organization of the nation and its spirit The new states set up in Europe by the treaty of Versailles for the most part have followed a policy of extreme economic nationalism For a time Great Britain and the United States seemed to be working back toward prewar conditions as rapidly as the unsettled state of world affairs allowed; but the grave economic errors perpetrated by private economic planning during the 1920's combined with the after-effects of the war to bring on the great depression of the early 1930's, and with it a marked recrudescence of national planning. Great Britain gave up her historic gold standard for a managed currency and free trade for moderate protection. In the United States, discouraged by three years of ineffectual efforts to stem the growth of unemployment by an administration that believed in "rugged individualism," the electorate put in power a party whose leader promised a New Deal in economic affairs. Even France, which had withstood the earlier stages of the world depression most stubbornly, has installed a radical ministry pledged to sweeping economic reforms.

VI

To my mind, this cursory survey of the relations between the state and economic enterprise in the western world since 1776 suggests that we are in for more rather than for less governmental planning in the calculable future. Economic forecasting is a notoriously hazardous enterprise, and political forecasting is perhaps even more risky. But the chances of forming approximately correct anticipations are best when we are dealing with a secular trend; when we can ascertain the more potent forces that have shaped this trend in the recent past, and when we have reason to believe that these forces will retain their character and their potency during the limited future of which we are thinking We expect technological progress to continue; for it rests upon scientific discovery, which does not seem to be approaching a limit, and upon man's desire to get larger returns for his economic efforts, which shows no signs of failing. Presumably, technological progress will continue to throw men out of work, to depreciate old investments, to shift sources of supply, to introduce novel products The growth of very large business enterprises has not been checked; the economic, political and social problems to which their operations give rise have not been solved. In nations that retain a capitalistic organization these changes will bear heavily upon numerous individuals, while they benefit others largely. Economic life will continue to be full of uncertainties, and those who suffer mischances will follow the precedents our generation is setting and make even larger demands for government aid. Social security legislation is more likely to expand than to contract in the great democracies, and dictatorial governments will practice paternalism. Business enterprisers will increase their efforts to limit or suppress competition; for the more we mechanize industry and specialize machinery, the heavier will be overhead costs and the more dangerous competition will become to vested interests.

The problems that the courts and the legislatures face in devising and enforcing rules of fair competition will grow more subtle and difficult. It will not be surprising if investors in great industries that are threatened with loss by technological progress organize campaigns for government purchase and operation. The draft upon exhaustible natural resources will grow greater and the movement for conservation through government regulation will wax stronger Communities will become increasingly interdependent and the task of planning water supplies, sewage disposal, protection of streams against pollution, highway systems, power lines and the like will be one in which the central governments will be forced to take a larger share Nor can we leave out of account the probability of future wars and the practical certainty that if they occur between great nations, each belligerent government will seek to effect a more drastic economic mobilization than was effected in the latest world war It is most unlikely that this trend toward national economic planning will rise steadily. Its course will be diversified by accelerations and retardations, perhaps by some vigorous reactions toward *laissez-faire*. But the indications seem to me fairly clear that in the long run men will try increasingly to use the power and resources of their governments to solve their economic problems even in those nations that escape social revolutions And, if it should turn out that Communism, or the corporative state, or some as yet unchristened form of economic organization makes a stronger appeal to the mass of people than does the complicated mixture of private enterprise and governmental regulation that is evolving in the capitalistic nations, then social revolutions may sweep the world, presumably carrying with them drastic governmental control over economic activities.

VII

Whether we fear or welcome these prospects of an evolutionary trend or a revolutionary shift toward governmental regulation, we must all agree that the relation of the state to private enterprise is a problem which the social sciences should join in attacking.

No scientifically minded man nowadays will assume that the immediate aim of this attack should be to pronounce a verdict that *laissez-faire* is better than governmental regulation, or that governmental regulation is better than *laissez-faire* It is not the business of the social sciences to say what is good and what bad, all they can do is to trace functional relationships among social processes, and so elucidate the most effective means of attaining whatever ends we set ourselves. Nor should any one expect a demonstration that private enterprise always begets one set of results, that governmental planning always begets a different set and that as citizens we have merely to choose which of the two sets we prefer The problem is not so simple as that On the contrary, it is a problem of numerous variables that may combine with one another in an indefinite number of ways, and a given combination may produce very different results when applied to different processes. Our choice does not lie between two sharply contrasted systems, private enterprise and governmental regulations, the real choices that we shall be making more or less deliberately are choices among the indefinitely numerous possible mixtures of private enterprise and governmental regulation, as applied to this, that or the other type of activity, under different conditions of time and place. Hence the common attack of the social sciences upon this problem should aim, not at finding "a solution," but at finding methods by which communities can carry on intelligently the process of working out the endless series of detailed solutions with which they must keep experimenting.

In dealing with this problem the social sciences are not confined to speculation. They have before them for analysis the experience of several autocratic governments that are professing to guide the economic evolution of their nations according to some system and the experience of several democratic peoples that are fumbling with the problem in different ways. On paper, the methods of autocratic governments look the more imposing to an outsider; but how plans are really made in present-day Russia, Italy and Germany I do not know. Perhaps the processes that go on behind the scenes are admirably organized to make use of the best intelligence available. Perhaps the critically important decisions are made on an inspirational basis by a leader whose genius is trusted as the guiding star of the state. Or the controlling group may believe that it is applying in practice rules deduced from a scientifically established body of principles. Or there may be a confused and shifting struggle among ambitious cliques, each seeking the favor of the powers that be. Probably a mixture of these various elements prevails in all autocratic governments, one element preponderating here, another there, one last year, another this year. Of course, it is part of the task of the social sciences to penetrate behind the stage sets painted by official propagandists, to find out as much as they can about how the national planning is actually done and to trace its consequences, direct and indirect, immediate and delayed, in social and political as well as in economic affairs. The rapidly growing literature about these experiments will become increasingly instructive if they are continued long enough to let their cumulative effects mature. But any one who glimpses the vastness and complexities of the researches called for will pardon me for considering only the processes of the democratic peoples, and primarily the people of this country.

As said before, American methods of applying intelligence to the guidance of economic evolution have run the gamut from a rather extreme reliance upon individual enterprise under some circumstances to a rather extreme reliance upon the federal government under other circumstances. However, one simple generalization may be ventured: we have seldom tried to work out national plans except when some considerable group among us has become seriously dissatisfied with the results of private enterprise, or of private enterprise as regulatd by local or state governments. In the life of the nation, planning plays the rôle that thinking plays in individual life. Both processes are resorted to typically to find ways of surmounting difficulties that occur in the course of routine behavior. And just as our individual thinking is commonly directed toward an immediate, specific difficulty, so most of our efforts at national planning have dealt with some single need that has been keenly felt by groups sufficiently numerous or sufficiently powerful to command attention. Let me call this "piecemeal planning." Examples are campaigns for federal aid to develop turnpikes and canals in our early days, for protective duties on imports, for the abolition of slavery, for free silver, for reduction of railroad rates, for curbing the "trusts," for "prohibition," for old-age pensions, and so on almost without end. The groups pushing these plans have been animated at times by philanthropic zeal and at times by sordid interests; some groups have relied upon fervid appeals to the moral conscience, some upon frank presentation of economic claims, some have resorted to bribery. What they have in common is advocacy of a measure designed to accomplish some one change in social organization, with slight regard to its collateral and long-run effects upon other social interests.

Of course piecemeal planning is defective in principle, however high its aims and however generous the spirit that inspires it. Each of the social sciences has its own way of demonstrating that all social processes are interrelated. When we alter the conditions under which one process operates we are certain to affect other processes. Many of these unplanned effects are negligible, but some are important; among the latter effects some may be pleasant surprises but others are likely to be unpleasant.

Also we know when we stop to think that the long-run effects of our reforms often differ widely from the immediate effects that we intended to produce. However heartily we approve the abolition of slavery we must admit that emancipation as we effected it without regard to the cultural status of the slaves was attended by grievous results not only for the former masters but also for the freedmen and for the relations between the northern and the southern states. No measure is so good in itself that its advocates are justified in thinking only of its direct and immediate effects. In short, we are not making the best use of what limited intelligence we possess when we plan on a piecemeal basis.

Though piecemeal planning is our common method of attempting to use the powers of government, on occasions we devise programs dealing with many matters at the same time. Every party platform makes pretensions to be a program of this sort; but we have learned not to take them seriously. Outstanding instances in our history are the adoption of the Articles of Confederation and the Constitution, the economic planning of Alexander Hamilton, the economic mobilization during the world war, and the attempt of our present administration to inaugurate a New Deal. In each instance, the country faced a grave emergency—only under such pressure have we ever set ourselves vigorously to the task of thinking out and putting into practice a comprehensive scheme of national policies. Two of these emergencies were produced by war, one by the inefficiency of existing political organization, two by economic troubles. When times are good, we let well enough alone. As yet we have not risen to the point of continuous systematic efforts to think out coordinated policies that will make what we deem satisfactory better still.

Planning in the face of national emergencies is commonly handicapped by the need for quick action. There is not time enough to bring the nation's full intelligence to bear upon the problem. The more intense the pressure the less the chance of doing a good job. The framers of the Constitution set an admirable precedent by taking time for deliberation; but our later emergency plans have been hastily concocted. Of course the inspirations of a desperate moment are sometimes fortunate; but we do not trust to luck in our most rational activities. To design an efficient National Industrial Recovery Act is vastly more difficult than to design an efficient bridge across the Golden Gate. The one task we essayed in a fine frenzy of good intentions and rushed it through in short order; the other we performed deliberately after elaborate study of the geological as well as the mechanical factors involved.

One reason why we act less rationally in devising national plans than in building bridges is that the sciences of social behavior lag far behind the natural sciences in certainty. If economists, political scientists and sociologists could tell us how certain proposals would work in practice with as much assurance as engineers can give, we would leave technical matters largely to them. The layman is naturally disinclined to trust professions whose members seem to be continually disagreeing with one another. That is a justifiable hesitation as matters stand. We might, however, if we chose, so alter the present status of affairs that we could make fuller use of the social sciences and, what is not less important, of the practical sagacity possessed by experienced citizens in many walks of life.

What I have in mind is an attempt to organize ourselves for deliberate and systematic study of social problems. Organization is often a critically important factor in determining the efficiency of group action. The same men who made a mess of national government under the Articles of Confederation made a success of national government under the Constitution. It is conceivable that we of the present generation who flounder so in public policy might reach a decidedly higher level of efficiency by following the example of reorganization set by the Fathers of the Republic.

Precisely what form an organization for the study of social problems should assume and how it should operate are delicate questions, but experience suggests some simple answers. First, the organization should be a continuing one, not like a constitutional convention that draws up a plan of government and adjourns *sine die;* for social problems are ever assuming new forms and the task of dealing with them is never finished. Second, to be effective the organization should center in a small board, responsible not for making technical studies and formulating plans—that task calls for more technical knowledge and more insight than any small group possesses—but for seeing that studies are made and that plans are formulated. It would be the board's task to make sure that in this work available knowledge is utilized to the full—not merely such contributions as social scientists could make, but also the contributions of experienced men of affairs, and the contributions of natural scientists, which are fundamental to many social problems. Also it would be the board's particular care to see that before measures were proposed for dealing with one issue the collateral effects, direct and indirect, immediate and delayed were considered. The board should endeavor to take up problems before they reach the emergency stage, while there is time for full consideration before reaching a decision. To enable it thus to focus the intelligence of the nation upon social problems of a wide and shifting range, the board should have a technical staff including men of many qualifications, means for obtaining professional assistance from any one whose counsel is needed and close contacts with government agencies, federal, state and local. It should foster the planning attitude toward public problems, cooperating with the state, regional and municipal planning organizations in all parts of the country. Finally, it should give all the interests affected by the issues under consideration an opportunity to present their views before it formulates proposals.

Sharing in the staff work of a National Planning Board would give social scientists a continuing opportunity of the sort that this Tercentenary Conference seeks to provide for a few days. The most effective way to secure genuine cooperation among men of different disciplines is to get them to unite in attacking common problems The specialists who participated in seeking solutions for the concrete problems taken up by a planning board would have facilities for thorough investigation, and they would have time to absorb in as large a measure as human limitations permit the significance of one another's contributions While serving the Board they would also be promoting the type of knowledge that the world most desperately needs—knowledge of human behavior.

An organization of this character would have the best chances of rendering service if it were accepted by public opinion as an agency of the federal government, but an agency empowered merely to draw up plans for consideration by the constituted authorities or the voters. No doubt the outcome of the deliberations upon many issues would be a recommendation to take no public action. In the many-faceted problem of how best to combine governmental regulation with private enterprise it might as often counsel a policy of *laissez-faire* as a policy of intervention. If I am right in forecasting a multitude of demands that the federal government extend its activities vigorously in the future, I may be right also in thinking that a planning organization, charged to study the collateral and the long-run effects of public policies, would be the best safeguard against ill-considered measures. Only the careless will jump to the conclusion that systematic study of national problems by a federal agency would accelerate the trend toward governmental regulation. It might have the opposite effect.

Needless to say, the most wisely guided organization for national planning would encounter opposition. Every attempt to extend the rôle of intelligence over new areas seems to many persons presumptuous or silly. Despite the plainest explanations that the central board was merely a device for focussing the practical wisdom and scientific knowledge of the whole community upon problems that have to be dealt with in some fashion, there would misunderstandings aplenty. Of course interests that thought themselves threatened would attack the organization with the weapons of prejudice, misrepresentation and ridicule. Reformers in a hurry would wax indignant over the deliberate methods of a board that tried to foresee consequences before it recommended action Early friends who expected the prompt formulation of sweeping plans embodying their own predilections might be turned by disappointment into enemies Unless public opinion really believes that it is worth while to think carefully about social problems, no planning organization worthy of the name could last long in a democracy.

Even if given a fair trial, the organization would find its technical tasks exceedingly difficult. Experienced men of affairs and social scientists know how hard it is to foresee the indirect and cumulative consequences of public policies, to approximate social gains and social costs, to find the most efficient ways of accomplishing given ends. And the ends to be aimed at are not given; they must be chosen. There have been occasions in American history when public opinion accepted a definite end as paramount; but these occasions have been rare and of brief duration. They vastly simplify the problem of national planning. For example, economic mobilization during the world war was facilitated by the fact that a large majority of the people were ready to sacrifice comfort, property and life for military success. But seldom is the national scale of values thus crystallized in a single dominant pattern. As a rule numerous limited ends command wide support, but no one end is predominant. To make matters more puzzling, the widely popular ends are likely to conflict with one another. I suppose that at present most people think it desirable to balance the federal budget, to reduce taxation, to increase employment and to keep the unemployed from suffering hunger and cold. Most of the time a national planning organization would have to work amidst confusion of this sort. That condition makes planning difficult, but not impossible. It is the condition that most individuals habitually face in their private planning. Somehow they manage to reach decisions despite the incompatibility among their desires. Presumably a wisely conducted planning organization could achieve a similar qualified success. In a democratic country, national planners would have to serve as an agency for accomplishing what the majority desired. But by throwing light upon the consequences that different lines of action would produce, they could contribute much toward making social valuations more rational. Perhaps in the long run the chief gain from trying to plant national policies in the light of their probable consequences would be the attainment of a more valid scale of social values than now prevails among us.

Whether this country is ready to organize its intelligence, practical and scientific, in an effort to guide the evolution of its institutions more wisely, I do not know. But a bill creating a National Planning Board along the lines that I have followed is now pending in Congress We may prefer to continue for years our past policy of piecemeal planning, supplemented in grave emergencies by sweeping changes made in a hurry. Or we may follow the example of those nations that have made a sudden plunge into fascism or communism. Our best chance of avoiding a dictatorship of some sort, with its compulsory regimentation of our lives, lies in infusing a larger measure of intelligence into our public policy.

THE SOCIAL IMPLICATIONS OF SCIENTIFIC RESEARCH IN ELECTRICAL COMMUNICATION

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IT has been suggested by those responsible for the program of the Harvard Tercentenary that, as a conclusion to the discussions in fundamental science which have marked your deliberations for the past two weeks, it would be appropriate to consider some of the practical results attendant upon the attempts to utilize science in our industrial and social affairs. They have suggested further that some discussion of the efficacy of introducing the powerful tools of the research laboratory into industry might be in order and that recent advances in telephony would supply good illustrative material.

In accepting their invitation I must express my appreciation of the honor they have conferred on the scientific men of the electrical communication industry and on me in designating me as their spokesman.

By suggesting this sort of termination for the discussions, I assume that the Tercentenary Committee had in mind not only practical values of an economic kind but likewise practical values of a social nature. After all, unless we are clear as to the existence of social values and are prepared to appraise them honestly and be guided by the results of our appraisal, the dollars and cents values of our work are more likely than not to turn to ashes in our hands.

The purpose which the Tercentenary Committee had in mind could be accomplished by scrutiny of examples from almost any of the great modern industries which have developed on the foundation facts, techniques and methods of science. None of them, however, I think more completely exemplifies the present and prospective economic and social values of practical applications of science than does that part of electrical communication which we designate as telephony. Nor is there any other in which, so far as I am aware, the fundamental principles of the scientific method have been extended so greatly to control accurately, uniformly and continuously the operation of a vast human and material mechanism. This control is imperative if the service is to have that degree of reliability demanded by the requirements of a social and business society organized to a large extent on the assumption that satisfactory telephone service is always instantly available.

Time does not permit any discussion in detail of how this has been made possible nor is there any necessity here of such discussion. All that need be mentioned is that among the principal factors have been a fortunate development of fundamental science itself in regions applicable to electrical communication; in an early appreciation of the power for advancement inherent in the slow but certain results of rigorously controlled experimentation, and in the almost equally early realization that in any community or region telephony must be a single service but one in which the physical means and human methods of operation are so chosen as to act harmoniously with the means and methods employed everywhere else.

Added to these and furnishing a rigid yardstick by which every new proposal must be measured is the fact that time is an all-important factor. On its purely physical side, two-way telephony to be of value must involve essentially instantaneous transmission of intelligence between terminals; otherwise normal conversation would not be possible. Nothing which introduces substantial deviation from this requirement is admissible, no matter how attractive it may be otherwise.

Further, every telephone circuit, whether it be between terminals in adjacent rooms or between those separated by half or more of the circumference of the earth, must be a cleared channel established with minimum delay on demand in order that the correspondents be brought immediately vis-à-vis. On the operational side, therefore, time is also an essential factor, and while it is inherently impossible to establish instantly any connection that may be asked for, everything that is reasonably possible is demanded to the end that every calling subscriber is served immediately on request.

In no other social service I am familiar with does the element of time play such an imperious controlling part.

While there are still vast areas both in the science and operational regions where we know that great progress is still possible, we have already gone sufficiently far in our development of the art to have telephone service begin to take on the form of complete universality. With it have come marked changes in our methods of social and business intercourse, in our economic and political machinery and in the problems presented to our courts for adjudication. All these things and their corresponding elements in other industries have their roots in science, and whether or not we are conscious of it, it is the possibilities and limitations of this science root structure which in the end will largely determine the resulting form of our society.

So far have we gone already in perfecting the adaptation of science to the art of telephony that most of us when we use the telephone are not even cognizant, except vaguely perhaps, of the fact that our ability to talk freely wherever and whenever we wish is the result of an infinite amount of work by the men in the laboratory. We are not conscious of the fact that these men have been and are being confronted daily with myriads of problems—all obstacles of one sort or another. Some they conquer and eliminate—some they learn to control and utilize. In the end, they have produced a gossamer web of filaments which, in spite of being beset with a multitude of enemies, they have succeeded in protecting and making available for its one and only function—that of enabling us to convey intelligible speech sounds to distant places. So effectively has this work been done that in many instances the men and women who install and operate the telephone plant are themselves unaware of the things done to make it smoothly operative.

This taking-for-granted attitude on the part of the many is common in every technical application of science to our daily usage. From it and from its corollary—action of a social, political or economic character with little or no understanding of the underlying and controlling forces—come most of our problems of proper social control of these new things. One of the biggest, if not the biggest, problem ahead of us is the educational problem of teaching a vast population, which is becoming more and more dependent on the things of applied science, enough of their inherent possibilities and limitations so that they can operate the social controls without danger of wrecking the machinery.

As one infinitesimal contribution to this educational problem and simply by way of illustrating in the field of telephony a few of the problems research men are solving every day in a multitude of industries, I shall give you a few demonstrations of things not normally observable when we use the telephone but which constitute some of the hidden factors I have mentioned. I shall begin by setting up a couple of telephone connections such as are regularly provided in the public service. This is merely to refresh your minds as to the results you obtain when you use the telephone Except for the fact that you will hear through a loud-speaking telephone, which for best results requires a transmission circuit slightly different from that ordinarily employed with a hand telephone, the result of one connection at least will be commonplace to all of you who have occasion to employ the long distance telephone. The other, which will be a long distance conference call, may be strange to most of you, although it is coming into somewhat general use in business operations Then we will pick these or a similar circuit apart a bit and show you a few of the many hidden forces which the research man has either had to overcome or develop and control in order to give the operating people and you long and complicated circuits which apparently operate like short and simple ones. I shall endeavor also to show you a few of the odd things which our knowledge of science has enabled us to utilize in giving types of telephone service which would otherwise be impossible.

Finally, with the collaboration of Mr. Dudley, you will have a glimpse through the crack that the research man has made in the wall surrounding a hitherto undeveloped field in the realm of communication possibilities.

All this is designed merely to give a springboard from which to project what seem to me a few plausible conclusions as to the social implications of scientific research in electrical communication and inferentially in many other fields as well.

Before going on to the demonstrations, it may be of interest to note briefly by analogy and otherwise what our present telephone facilities here in the United States really provide and some of the grosser effects which would result from their substantial annihilation.

Imagine direct railroad tracks from every city, village and hamlet to every other city, village and hamlet. Imagine a train on every track, steam up, ready to start at a moment's notice to any destination. Imagine the track facilities so ample that, no matter how numerous the trains, there are no delays either in going or returning. Imagine, further, that the trains move with incredible speed which in many cases is virtually that of light Here we have in substance the achievement of modern telephony when we realize that the cargo on the trains is human thought as conveyed by the spoken word. Recalling the words which Emerson wrote years ago at the completion of the first Atlantic cable—

> The lightning has run masterless too long;
> He must to school and learn his verb and noun
> And teach his nimbleness to earn his wage,
> Spelling with guided tongue man's messages—

how uncommonly prophetic these have proved! How well the lightning has learned his lesson!

Without the telephone, modern tall buildings and the correlated extreme density of populations in many of our urban developments would be either impossible or more encumbrances than aids to life and business. To carry by messenger the communications which enter and leave a tall office building by telephone during the rush hours, would block corridors and elevators and produce unprecedented traffic jams in the streets outside. For every person who walks along a busy city street, the telephone enables a much larger number to project their thoughts and personalities along the circuits below the street. Usually the telephone delivers a message and brings an answer in less than the time it would take to transcribe it for a messenger.

Merely to mention the number of calls completed each year over our American telephone system takes us at once into astronomical magnitudes. For the past year, the number was twenty-five billion. While the major portion of these were local calls, a vast number were long distance and, with added facilities and the prospect that through further research costs can be lowered, there is every reason to believe that the time is not far distant when the number will be increased many fold.

When one attempts either by word of mouth or by demonstration to explain the recent problems of telephony and how they are being overcome, he finds that he has a uniquely difficult piece of work in hand. He must discourse upon a structure, the long telephone line, which neither he nor any one in his audience has ever seen in its entirety, and he must, unless addressing a group of his own kind, put into words a host of concepts which find their proper expression only in mathematical symbols and processes or in the special language of the physicist. If I could transport you rapidly out across the continent three thousand miles or so, thus enabling you in the course of a few minutes to visualize what a complex thing a modern long distance telephone line actually is, I might hope to convey to you a superficial conception of the elaborate and fragile thing I am talking about. Only thus would many of you sense how remarkable it is that this frail far-flung structure should be endowed with surprising electrical stability and immunity to meteorological and man-made disturbances.

Were we to make such a flight, what actually would we find over and above the pairs of wires which every one recognizes as among the constituents of all telephone circuits—the wires which in one form, the open or exposed form, de Chavannes depicted in his painting in the Boston Public Library? We would find as a matter of fact, that these pairs of open wires represent a type of construction which is now rather in the minority even for long distance telephony. For reasons of better protection and stability, particularly in regard to electrical leakage, the wires composing even very long circuits are now frequently packed tightly together and enveloped in an impervious lead sheath to form a cable in which neutral gas, such as nitrogen, is maintained under pressure.

Continuing our imaginary flight, we would encounter on each of the hundreds of pairs of wires within each cable and at absolutely regular intervals varying from about five eighths mile to one and one eighth miles on different circuits, a loading coil—a coil of wire on a special magnetic core whose function is to assist the speech currents, as they travel, to overcome the large attenuating effect of the electrostatic capacity of the tightly packed wires. These coils, of which there may be as many as two or three thousand called into play in the handling of a single message, must be identical to a degree characteristic of the watchmaker's precision. Next, there is the repeated and uniform twisting of each pair of wires at its own particular pitch to secure such nicety of balance, both electrostatic and electromagnetic, that not more than a millionth of the power of a telephone circuit will pass over inductively to any neighboring circuit. Then at intervals of fifty miles for certain types of cables, and at shorter intervals—even as low as ten miles on certain newly projected types—we would encounter the thermionic amplifiers which restore the message energy after attenuation by resistance and other forms of dissipation. Closely associated with certain of these amplifiers are the regulators which automatically counteract the effect of changes in conductor resistance induced by changes in temperature. As an illustration of how important the regulators are, they must allow the total amplification of a long circuit to increase between winter and summer by as much as the factor

10^{20}. Then too there are the smaller diurnal variations which it is even more important to compensate for automatically because they are naturally of a very irregular pattern. The emergence of the sun from behind clouds or an icy blast along one section of a toll cable is registered almost immediately by a large alteration in the attenuation of the circuits within it. In case a cable is placed underground, the temperature changes to which it is subjected are of course of smaller amplitude and longer period, but for them too it has been found best to compensate on the automatic pilot wire basis

In our overland flight we would actually see many other essential telephonic devices which cooperate to insure the steady and uninterrupted operation of the lines, but since our time is limited I must stop with the bolder details of the picture. I hope they will be sufficient to give you at least some visualization of what science has enabled the telephone engineer to accomplish. So stable in operation is the telephone plant of to-day that in spite of the apparently fragile nature of its long lines, which in turn depend upon the uninterrupted functioning of many thousands of delicate electronic devices, it is available every hour of the day, day in and out. Along with growth in reliability, despite an ever-increasing dependence on delicate structures, has come a marked increase in the amount and scope of facilities as a result of the continually decreasing cost of circuits brought about by research. This combination of enhanced reliability, at cost sufficiently low to permit circuits to be provided in profusion, has made it possible for you to reach a distant party without leaving the telephone and has made operating delays a rarity rather than a commonplace.

To illustrate this point I am going to place one or two long distance calls. Even after thirty odd years' intimate association with telephone development, I still confess to a certain awe at the speed with which the telephone operators are to-day able to transport one about the country. In a sense, we are about to bring that painting by de Chavannes to life, and because I want you to hear with me how the girls operate the circuits I have arranged that whatever is audible on this telephone will also be reproduced by the loud speakers which you see here on the stage. The first call I will place will be for Dr. Millikan in Pasadena.

Boston A Operator: "Number, please."

Dr. Jewett says: "I would like to talk to Pasadena, Calif."

Boston A Operator: "I will connect you with the toll operator."

Audience hears click.

Boston Toll Operator: "Toll Operator."

Dr. Jewett: "I would like to talk to Dr. Millikan at Pasadena, Calif., Terrace 7125."

Boston Toll Operator: "Hold the line, please."

Audience hears several clicks as toll operator rings New York.

N. Y. Inward Operator answers: "New York."

Boston Toll Operator says: "RX."

N. Y. Inward Operator says: "Right."

N. Y. Through Operator answers: "RX."

Boston Toll Operator says: "Los Angeles."

N. Y. Through Operator says: "Right."

Audience hears several clicks as toll operator rings Los Angeles.

Los Angeles Operator answers: "Los Angeles."

Boston Toll Operator says: "Terrace 7125."

Los Angeles Inward Operator says: "Right."

Boston Toll Operator says: "Your number, please."

Dr. Jewett says: "Hancock 0514."

Audience hears audible ringing at Los Angeles.

Dr. Millikan's office answers: "This is Terrace 7125."

Boston Toll Operator says: "Dr. Millikan, please, Boston is calling."

Dr. Millikan answers: "This is Dr. Millikan speaking."

Boston Toll Operator says: "Ready with Pasadena."

(A brief dialogue followed in which Professor Millikan said that, as he had been prevented from attending the Tercentenary in person, he was particularly pleased at having the opportunity to participate telephonically in the event.)

I will next have you listen in on what we term a conference call. Such calls require a certain amount of prearrangement, depending upon the number of participants. In the present instance, I have asked five gentlemen in five different cities to participate. The five cities are New York, Chicago, St. Louis, San Francisco and Atlanta, and the five speakers are intimate telephone associates of mine.

As you have doubtless already inferred, the conference call brings several persons together in telephonic communication so that each can speak and listen to all the others. Conference calls, although but recently introduced, are much in demand, and I need not, I think, argue at any length the case for their significance in working out what appears to be the destiny of the telephone as providing a national nervous system. Through prearrangements these associates of mine have just been connected to us through the conference system and I will now talk with them.

> "Good afternoon, gentlemen! I am speaking from Sanders Theater in Cambridge, where about 1,200 guests of the Harvard Tercentenary are assembled. I have just explained what a conference call is and now I want to show the audience that those who participate in such a call are in effect seated together around a table. I shall not call a roll but suppose each of you gentlemen announce yourself and your location." (There followed brief exchanges of remarks among the five participants.)

So much by way of refreshing your minds on what normal telephone calls are like. I am now going to take a long circuit similar to those we have just used and perform some experiments with it merely to show you a few of the obstacles with which the research men have had to contend in order to give us our apparently simple circuits.

It won't be practicable to have the circuit here before you because it is actually 1,700 miles long and extends in cable from Cambridge to Charlotte, N. C., and back. You will have to take my word for it therefore when I say that it includes approximately 3,000 loading coils, 40 equally spaced vacuum tube amplifiers, pilot wire regulators which control their gain to compensate for changes in temperature, and other devices, such as echo suppressors, the purpose of which I will return to in a moment. You will not, however, have to take my word for the curious phenomena which such a circuit exhibits—phenomena which are displayed best in a very long circuit—because with the aid of the loud speakers you will all be able to observe the circuit's performance when normal conditions of operation are disturbed.

At the outset let me say a word or two as to a basic characteristic of long speech highways in which they differ fundamentally from other highways. The telephonic highway must respond as a single unit from end to end or not at all. It is a single entity, almost a living organism which, if disturbed at one point, reacts throughout. As a coordinated, balanced and self-contained unit, it is undoubtedly the most extended structure man has thus far built. Not like the highways for rolling stock which may be torn up for considerable sections without interrupting the flow of through traffic, we must consider the telephone line, even though thousands of miles long, as a single integrated entity. This characteristic underlies the demonstrations I have arranged.

Familiarity on your part with the general functioning of the vacuum tube, now indispensable as an amplifier in all forms of electrical communication, I must assume. We will pass on at once to consider the degree of perfection as regards accuracy and stability to which the device has been brought in the telephone plant. As I mentioned earlier, I have here the terminals of a circuit 1,700 miles long which is looped down to Charlotte, N. C., and which contains 40 amplifiers, each supplying an average gain rather greater than ten-fold. This gain is required, since at each amplifier the speech current has been attenuated by resistance and other losses to about the value it must have at the receiving terminal. Further transmission without distortionless amplification would so weaken the current as to make it useless. A graph of current along the line would present a saw-tooth appearance—the value on reaching each repeater or amplifier being a minimum and beyond each amplifier being substantially that at the sending end.

Since the speech current passes through each amplifier successively, it receives this ten-fold boost at each so that after having passed the second amplifier the total gain is 10×10; at the third, it is $10 \times 10 \times 10$, and the total amplification from end to end of the circuit is 10^{40}, *i.e.*, 10 with 39 naughts after it. Here indeed we are dealing with astronomical magnitudes. In terms of a more familiar physical quantity, this is multiplication about equivalent to taking a single atom of hydrogen and magnifying it until it fills the entire solar system. Surprising as it is that such amplifications are attainable, it is even more unexpected to find them produced as an everyday affair with so little distortion that the final product at the receiving end is essentially indistinguishable from the original and so perfectly under control that the overall variation in magnitude is negligible. Just to verify that there is no perceptible distortion I will ask Mr. Thompson, one of my assistants, to enter the booth in the corner and speak to you, first directly through the loud speakers and then over the 1,700-mile looped circuit. (From the booth Mr. Thompson spoke as follows.)

"I am now talking to you from the booth on the stage and speaking directly through the loud speakers "

(Click) — — — (Pause).

"Now you hear me through 1,700 miles of cable circuit."

(Pause) — — — (Click).

"Now the cable has been removed again."

(Pause) — — — (Click).

"And now you hear me through it. I doubt if you notice any appreciable difference in my voice whether it reaches you direct or through this 1,700 mile line." (Dr. Jewett then resumed.)

Such speech transmission represents the present culmination of a prolonged study of circuit characteristics and countless laboratory investigations to discover the best instrumentalities. It would scarcely exceed the truth to say that we are dealing here with the same perfect balancing of processes that a living body displays and which nature has attained after speculative ages of evolution. If, for example, the speech current at any point in the circuit is permitted to rise substantially, the capacity of the next amplifier will be exceeded, with resultant distortion. This effect can readily be illustrated. To do this I will again ask Mr. Thompson from his vantage point in the booth to speak over the circuit first in its normal adjustment and then with one of the amplifiers subjected to overload conditions and you will have no difficulty in distinguishing between the two conditions. When one amplifier is overloaded his words are scarcely recognizable.

Under-amplification represents an equally serious menace to satisfactory transmission. It results in the message current being masked by the stray electric currents present on every long line. The telephonic currents must at all times exceed these stray currents by a suitable margin to prevent loss of intelligibility. (Here Mr. Thompson spoke again over the circuit—first in its normal condition, and then under somewhat exaggerated conditions by increasing the noise at the expense of his voice.)

To a certain extent, the telephone engineer can control the noise level on his circuits, *i.e.*, the magnitude of the stray electric currents with which his message currents must compete. By the maintenance of perfect electric and magnetic balance with respect to all neighboring circuits—telephone, telegraph and power

—it would be possible theoretically to eliminate the currents, since they are due to induction. Perfect balance is out of the question as a practical matter, however, for circuits of the existing art. What the telephone engineer is concerned with is that degree of perfection which it is economical to attain and maintain. In other words, his balance must admit of economic as well as electrical and magnetic considerations.

There are certain types of telephone circuits, such as the new coaxial cable being installed between New York and Philadelphia, quite different from those we are using to-day and not yet in commercial operation but whose development is well advanced, which do permit either of perfect electric balancing or of shielding against outside disturbances. Even in these circuits, however, the noise factor still sets limits of attenuation and amplification. In this case it is not the noise of induction but is the noise resulting from the random motion of the conduction electrons in the wires themselves with which we have to deal.

One way of conceiving of the noise of random motion is this: We may think of electricity in a metallic conductor as forming a level sea. The heat motion of the molecules of the metal set up tiny waves on this ocean that strike and break against the ends of the conductor. Given enough amplification we can hear the surf of the electric sea beating on its shores.

I have here three similar resistances of wire wound on quartz supports. They may be connected in turn to a high-gain amplifier and the loud speaker so that their natural state of electrical unrest can be heard. One is cooled in liquid air, one is at room temperature, and the third is heated to red heat in an electric furnace. Connecting in first the coil at room temperature you hear the hissing of the electric surf quite plainly. Of course the current of random motion is extremely small, the amplification being such that the current actuating the loud speaker is approximately one hundred million times the rapid current surges in the resistance itself.

Now I will let you hear the louder hiss of the hot resistance and then the gentler hiss of the cold one

Practically, of course, we can not evade this limiting disturbance by cooling our telephone lines in liquid air. Instead, since the internal noise of the metal affects the entire audible range of frequencies, we have to make certain always that our man-made speech waves are higher than the waves of heat motion anywhere and everywhere in the circuit.

In this respect the inherent molecular noise is more difficult to cope with than the noise of inductive interference, since there is no way of filtering it out from the speech currents.

Let us turn now to quite another problem Telephone engineers are commonly concerned with transmitting speech in two directions. Sometimes this is done over a single pair of wires, and at other times a separate pair of wires or transmission path is provided for each direction of transmission over the major portion of the distance. In either case, at least at the terminals, there is a common circuit.

It is practically impossible at the terminals to arrange matters so that the energy of the telephonic current is completely absorbed in the receiver. What is not absorbed is, of course, reflected back toward the transmitting end.

Such reflections, together with the fact that in long circuits the electric waves take a noticeable, though very short, time for transmission, create echo effects. In the case of our present circuit it takes 0.13 second for the current to travel 850 miles and return—a total of 1,700 miles. This means that the person at the transmitting end of such an 850-mile two-way circuit will hear an echo of his own voice reflected from the farther end unless means are taken to prevent it. This echo returns in 0.13 second. I will now set up the former circuit to show you how such an echo sounds I will ask Mr. Thompson first to tap his transmitter several times, and then speak a number of words with a pause after each one. Each time he does so, if you listen closely you will hear the echo caused by the current which has traveled to North Carolina and back. Now, Mr Thompson, will you please tap.

Tap Tap— Tap—Tap— Tap— Tap—

Now will you please say a few words tap- —

This is is is the-e 300th-th an n niver sary-y of Harvard-rd Un-n iver-isity-y

On long circuits such as this one where echoes are a factor, the telephone engineers have been forced to devise echo suppressors in order to block out the echo currents and thus prevent their disturbing the speakers.

Actually, of course, we frequently have reflection not only at the far end of the circuit but again at the sending end, so that the energy will be reflected back and forth several times. These multiple echoes can be demonstrated also I will ask Mr. Thompson to repeat.

This phenomenon of reechoing or multiple echoes can be followed further if I have the amplification here in the theater increased gradually as the echoes tend to drop off, thus keeping them more or less at constant volume and having the sound finally buried in noise.

tap—— tap——

repeated 30 or 40 times and gradually diminuendo, while the circuit noise at first inaudible increases until finally it overpowers the taps.

The phenomenon of reflection, aside from being troublesome when it produces echoes, also places a stability requirement upon our thermionic amplifiers—the telephone repeaters. In a long circuit, were even one or two of them sufficiently unstable so as to increase their gain materially, the reflected currents would be large enough to cause sustained oscillation or singing of the circuit as a whole. In the case of a circuit with many repeaters, the telephone engineer must make certain that spontaneous fluctuations in gain are reduced to a negligible percentage. The circuit which I have been demonstrating can readily be unbalanced to the point of singing, and you might be interested in hearing the result. While Mr. Thompson speaks the singing condition will be introduced and you will note how his words are gradually lost in the more or less pure tone which is generated by the oscillating condition

Turning from these transmission considerations, let us inquire a little into speech itself. I mentioned a few moments ago that by the preservation of proper balance between adjacent circuits they will not seriously crosstalk into one another; in other words, transmission by wire is secret. But when we come to radio transmission we can not safeguard our messages in the same way The ether is a world-wide party line, and no matter what special type of radio system is resorted to, an eavesdropper can readily succeed in tapping the transmission. To insure privacy it therefore becomes necessary to operate on speech itself—before transmission—to throw it into some hopelessly unintelligible form, but of course with the assurance that at the receiving end it will be possible by providing an inverse correcting device to restore the speech to intelligible form before it goes to the subscriber.

Many radio receivers in general home use to-day are capable of listening to short wave stations around the world as well as to broadcasting stations. Because of this, it would be feasible for the broadcasting listeners to overhear conversations over commercial radio telephone circuits if preventive measures were not applied. In order to insure privacy to the users of transatlantic service, so-called privacy apparatus is connected in the transmitting and receiving circuits of the radio links. This apparatus takes the normal speech from the subscriber and mutilates it in such a way that, if it is picked up on the air, it will be unintelligible to the eavesdropper. The proper apparatus in the commercial radio link at the receiving point restores the mutilated speech to original form so that the subscriber at the other end is unaware that any transformation has taken place

Two types of privacy devices are in general use in our overseas services. The first type is known as the inverter and the second type is known as the band-splitting system These devices I will demonstrate by connecting the loud speakers here to a circuit to New York, from which point you will hear Mr Joseph Richey, chief overseas technical operator, speaking to you and making use of the regular equipment there. (Mr Richey showed how by switching in one of the privacy devices he could at will make his words quite unintelligible. He also recorded a bit of this unintelligible speech on a phonograph record and showed how its clarity could be restored by transmission through the complementary device)

Now for a look through the crack into the undeveloped realm previously mentioned. This involves quite a different approach which we have been making to the subject of speech. Superficially it is rather amusing.

In this development our research men have sought to analyze the fundamentals of speech production with surprising results. They have found that intelligible speech is produced by relatively few controlling factors of the speech mechanism and that by analyzing speech instantaneously to obtain quantitatively the values of these controlling factors surprisingly accurate reproduction of the original speech can be obtained by applying currents representing these factors to a proper electrical synthesizer which reproduces speech in its original form.

The method, as you will witness in a moment, is also capable of producing some very weird effects.

All this work is very recent, and this occasion is the first public statement of it, as nothing has yet been published in the scientific journals Time will not permit of anything more than a sketchy statement of the general method and a few demonstrations of results.

Before introducing Mr Dudley, the man primarily responsible for this amazing piece of work, who will conduct the demonstrations and give you such explanation as time permits, I may be permitted to say just a further word or two by way of preliminary explanation.

As to the analysis, we find that speech consists inherently of two—I rather hesitate to state the fact– not musical or dulcet tones—nothing more nor less than two noises. We shall let you listen to these noises. Then we shall show that when modulated properly and mixed properly, the result is perfectly acceptable speech Each of the noises has a pitch characteristic, and each of course has a loudness characteristic. These are analyzed and the result applied to the synthesizer.

Before proceeding further with the explanation, I ought to mention that this investigation is still very much of a laboratory affair. It will be necessary for us in effect to visit the laboratory in New York in order to witness a demonstration (At this point Mr. Dudley demonstrated how successfully his machine could mimic the voice both when speaking and singing. Dr. Jewett then concluded as follows.)

These few demonstrations and all that we have told you are but minute examples of the results that have come from organized scientific research in the one field of electrical communication. Most of what we now have or of what we envisage for the future could not have been obtained except through rigorous application of the facts and methods of science in a broad frontal attack such as organized cooperative effort alone can make. It is not too much to expect that a continuation of the method will ultimately result in the substantial destruction of the barrier to conversation wherever and whenever desired which distance has imposed in the past. Since there is even now no physical obstacle of distance, this is simply another way of saying that a continuation of organized research gives promise of providing speech channels so numerous and relatively so cheap that the economic barriers to full usage will be obliterated.

When this time comes, society for the first time in its long evolutionary history will, through the varied forms of electrical communication, have a complete nervous system. In many respects it will present striking similarities to man's nervous system. It can not help but speed up what Spencer termed superorganic evolution and will in fact make possible a type of political state which could not develop without it.

Time does not permit any elaboration of the effects on society of this obliteration of distance as they influence the action and interaction of our human social atoms. My purpose here to-day has been served if I have conveyed to you some understanding of what scientific research in the communication field has already done and what it seems prepared to do in the future in the way of putting men everywhere in position to act with the same facilities, as regards interchange of ideas, as if they were in one room.

One could spend hours developing in detail the multitude of ways in which the things evolved by organized scientific research in the field of electrical communication have influenced our modes of life. When all is said, however, the broad implications are to be found in the result just mentioned, namely, that through it we have already gone a long way toward providing society with a complete nervous system and have every prospect of finishing the job.

My purpose has been served further if it has given you a better idea of the vast power in coordinated research for solving incredibly intricate problems of a very practical nature and for developing adequate controls over multitudinous conflicting forces in such simple form that they can be operated easily by essentially unskilled people.

What organized scientific research has done and is doing in the field of communication is being repeated in a host of other fields. Everywhere there is growing evidence that the power inherent in the scientific method when applied to the prosaic affairs of everyday life is coming more and more to be understood.

The ever increasing flood of new tools which fundamental and applied science are giving us is obvious. So, too, are the initial results on society of their mass introduction into it. What is not so obvious are the processes by which they will gradually be fitted smoothly into an orderly society built up around them.

The one thing that is quite clear to me is that since these new tools are the direct result of operating a powerful method by skilled people, it is imperative if full social value is to be obtained that the method which produced them be extended and that men and women be truly trained to apply it—not to produce new things but show us how properly to use them. In this it will not suffice to do what we have so frequently done in the past, feel that we are making progress by giving things awe-inspiring titles which serve merely to cloak shallowness of understanding.

To the extent, however, that we are able to introduce the elements of this proven method of rigidly controlled and coordinated experimentation into the stream of our social and political evolution, to that extent will we be able to simplify and expedite our progress.

THE PROGRESS OF SCIENCE

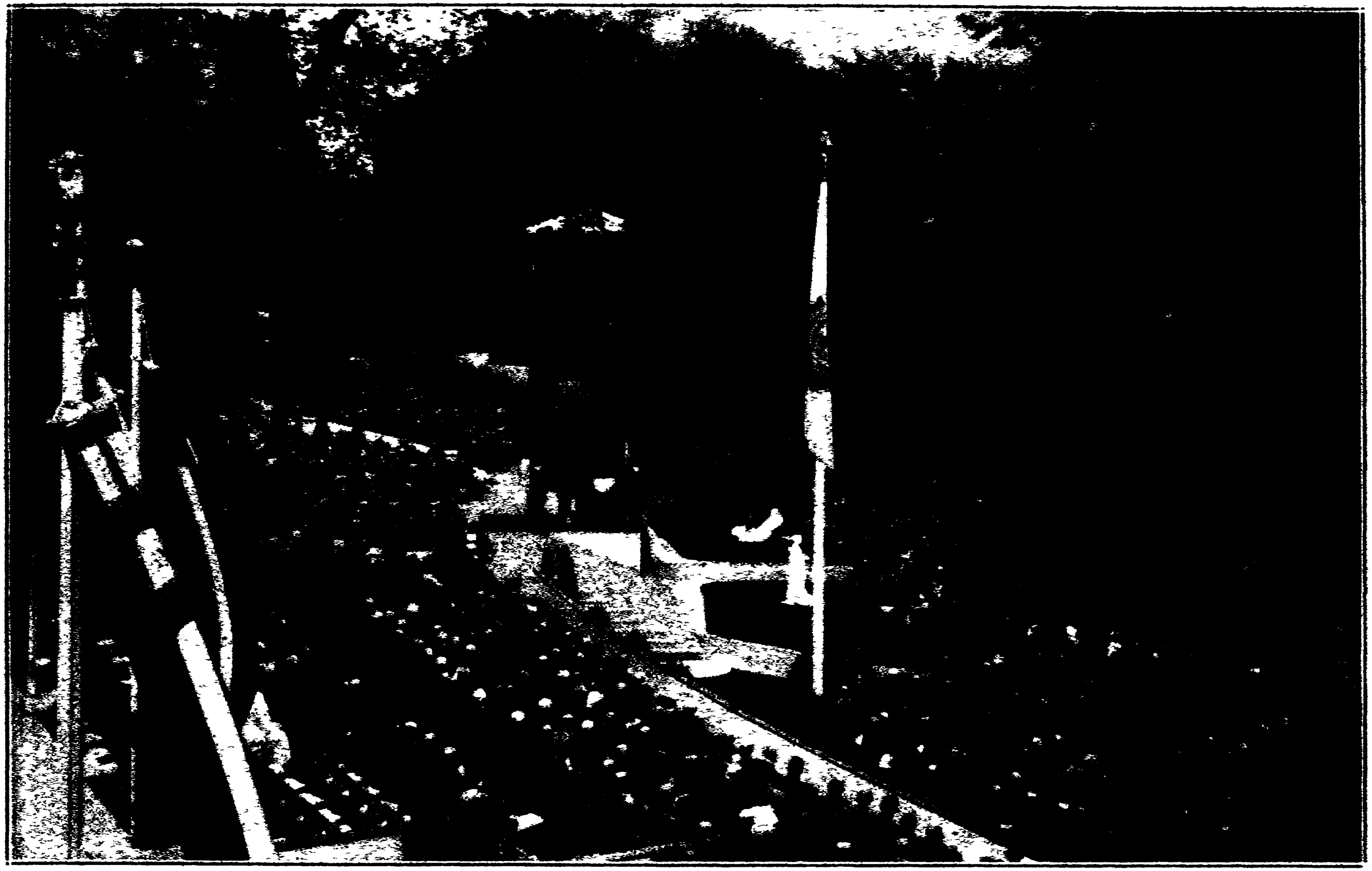
THE CELEBRATION OF THE HARVARD TERCENTENARY

HARVARD UNIVERSITY celebrated the three hundredth anniversary of its foundation on September 16, 17 and 18. Preceding the ceremonies there was a Conference of Arts and Sciences, held from August 31 to September 12. At this conference some seventy papers and addresses were presented by leading scholars and scientific men from the United States and from fourteen foreign countries. THE SCIENTIFIC MONTHLY has the privilege of printing in the present issue a number of these addresses and thus is enabled to do its part toward demonstrating the remarkable character of the program commemorating an event unparalleled in the history of American education.

The three tercentenary days opened with a reception in Sanders Theater on the afternoon of September 16, when each of the 551 delegates was greeted by President Conant. Their reception was followed by an address by him to which a response on behalf of all the delegates was made in French by the senior delegate from the University of Paris, the mathematician Professor Élie Cartan After the reception tea was served in the delta or yard of Memorial Hall. In the evening the Boston Symphony Orchestra gave a concert under the direction of Dr. Sergei Koussevitsky. There were other symphony concerts on the two following days, at the latter of which there were choruses sung by the Tercentenary Chorus made up of present and former members of the Harvard Glee Club and the Radcliffe Choral Society.

The meeting of the Associated Harvard Clubs was the feature of the morning of Alumni Day, September 17. Following a service of thanksgiving and remembrance in the Memorial Church, a meeting was held in the tercentenary theater set up in the Harvard yard with seats for 15,000 people. After the roll of classes had been called President Conant reported on the contents of the package which was sealed in 1836 by President Josiah Quincy. The package contained letters written by alumni in answer to the invitation to the two hundredth anniversary celebration of the university. After quoting from those documents, President Conant sealed a similar package to be opened by the president of the university in 2036.

There were speeches by three undergraduate students, the unveiling of a bust of the late Dean Briggs, the presentation of gifts from alumni in China and Japan and of a gift of $5,000 from men not graduates of Harvard. The faculties of the university gave a luncheon in Memorial Hall in honor of the visiting delegates. Informal speeches were delivered by five delegates, representing universities of Europe, Asia and South America, and by one delegate who voiced the good-will of universities of the United States. These were Sir Frederick G. Hopkins, Professor Joseph Bedier, Professor Tullio Levi-Civita, Professor Hu Shih, Professor Bernardo Alberto Houssay and President Lotus D. Coffman. The toastmaster was Dean Sperry. In the evening the Harvard Chapter of the fraternity of Phi Beta Kappa held exercises, at which the address was made by Professor Bronislaw Malinowski, of the University of London, and a poem was read by Professor Robert S. Hillyer, of Harvard University. Later in the evening a reception was held at the Isabella Stewart Gardner Museum in Boston for delegates from other universities and learned societies. Also at 9 o'clock began the illumination of the river front, arranged as a part of the Undergraduate Celebration.



TERCENTENARY MEETING OF ASSOCIATED HARVARD CLUBS IN THE HARVARD YARD

ON THE STAGE ARE THE OFFICERS AND SPEAKERS, THE DELEGATES AND THE FACULTY OF HARVARD UNIVERSITY THE AUDIENCE OF NEARLY 15,000 IS PARTLY SHOWN.

THE ROSTRUM OF THE TERCENTENARY THEATER

JOHN MASEFIELD, THE ENGLISH POET LAUREATE, IS READING THE TERCENTENARY POEM.

On the third day of the celebration the morning was given up to the formal exercises of the university, and in the afternoon the Harvard Alumni Association held its meeting After processions of alumni and delegates the bells of Southwark Cathedral, London, where John Harvard was baptized in 1607, were heard as carried by radio across the Atlantic.

Dean W. L. Sperry, of the Divinity School, gave the invocation, and Professor E. K. Rand delivered a salutatory oration in Latin. Then followed an address on "The Founding of Harvard College" by Professor S. E. Morison; "Greetings from the Commonwealth" by Governor James M. Curley, of Massachusetts; addresses by President Conant to the Universities of Paris, Oxford and Cambridge; "Lines Suggested by the Tercentenary," a poem by John Masefield, poet laureate of England; President Conant's oration, "The University Tradition in America—Yesterday and To-morrow", the conferring of sixty-two honorary degrees on those who took part in the Conference of Arts and Sciences, and the benediction by the Rt. Rev William Lawrence. The Tercentenary Chorus, under the direction of Professor Davison, sang selections at appropriate times.

Owing to the rain which began to fall during the exercises, arrangements were made for transferring the meeting of the Alumni Association from the open theater in the Yard to Sanders Theater with radio transmission to other auditoriums.

President Emeritus Lowell, as "President of the Day," presided at the meeting of the Alumni Association in the afternoon. He introduced first President Conant, and then a brief message was received by radio from Stanley

—*Photograph from the Boston Traveler*

DR. A. LAWRENCE LOWELL
PRESIDENT EMERITUS OF HARVARD UNIVERSITY.

Baldwin, chancellor of Cambridge University. The other speakers were: Judge Learned Hand, '93, president of the Harvard Alumni Association; Franklin D. Roosevelt, President of the United States; James Rowland Angell, president of Yale University; Alexander Dunlop Lindsay, master of Balliol College and vice-chancellor of Oxford University, and George R. Agassiz, president of the Board of Overseers. At the end of the proceedings, President Conant moved that the meeting be adjourned to September 18, 2036.

THE HARVARD TERCENTENARY CONFERENCE OF ARTS AND SCIENCES

SIXTY-SEVEN of the world's most distinguished scholars and scientists, including eleven winners of the Nobel prize, gathered in Cambridge, Massachusetts, during the first two weeks of September to participate in the Harvard Tercentenary Conference of Arts and Sciences. Outstanding thinkers in numerous fields of specialized endeavor, the participants came not merely to report on progress within the limits of these fields but to approach a broader conception of man's nature, his learning and his functions as interpreted from these widely divergent viewpoints. Astronomers, philosophers, economists, chemists, historians, biologists, psychologists, mathematicians, geologists, physicists and a host of other specialists presented their contributions in a novel attempt to unite the isolated branches of modern scholarship into a single yet general investigation of human life.

The program, however, did not pretend to be all-inclusive. As Jerome D. Greene, director of the Tercentenary, explained, the encyclopedic range of human knowledge could not have been surveyed during the conference or even in a whole series of conferences. Nor did Harvard pretend to make an authoritative selection of the most important problems or the most competent students of each problem. Instead the conference was arranged on the theory that if men of great distinction in various fields could be brought together to give their best to their fellow-workers, such a gathering would inevitably be of the greatest importance.

The breadth of the five symposia into which the conference was divided is indicated by their titles. Factors Determining Human Behavior; Authority and the Individual; Independence, Convergence and Borrowing in Institutions, Thought and Art; The Biological Sciences, and The Physical Sciences. Yet all were related in the general plan of the conference in that all concerned man, his behavior, his knowledge, his civilization.

"The need of finding some unity in a maze of modern scholarship has been increasingly felt, not merely for the purposes of education, but for the guidance and what might be called the cross-fertilization of research itself," Mr. Greene explained. "Each address represents a characteristic way of thought and method of study by which men have come to understand one side of a vast problem which is here being studied from many sides. As a whole, therefore, the addresses comprise a series of typical methods and outlooks which jointly play their part in approaching the great problem. They form an attempt, as vital to the future of scholarship as it is untried, to orient different methods and fields of study with one another toward the goal of seeing human life in a truer perspective."

In its opening week the conference appropriately considered the oldest sciences known to man, astronomy and mathematics, holding sessions jointly with the American Mathematical Society, the Mathematical Association of America, the Institute of Mathematical Statistics and the American Astronomical Association. Members of these groups, living and eating together with the participants in Harvard dormitories, formed the nucleus of the 2,500 American and Canadian scholars to whom attendance at the conference was limited. Since one of the most important purposes of the conference, in addition to unifying the academic world, was to impress the non-academic public with the value of universities, all the sessions were broadcast over an international network, the meetings were fully reported in the press of the nation and, in the case of the more popular evening lectures, the public was admitted without charge. In addition, papers in three of the five symposia are being published by the Harvard University Press, while those in the physical and biological sciences will appear in various scientific journals. To facilitate press coverage of the often highly technical papers, many participants in the conference, as well as members of the Harvard faculty well acquainted with the research being reported, held a series of press conferences with newspapermen, explaining in general terms the content and significance of various papers.

The value of this arrangement was emphasized early in the conference, when Professor Élie Joseph Cartan, of the University of Paris, presented what was probably the most important paper of the mathematics sessions. Although Professor Cartan spoke French and was dealing with a problem so abstruse that

—*Photograph from the Boston Post*

REGISTRATION OF MATHEMATICIANS

DEAN GEORGE D. BIRKHOFF, OF HARVARD UNIVERSITY; PROFESSOR ELIE J. CARTAN, OF PARIS, AND PROFESSOR CONSTANTIN CARATHÉODORY.

outstanding mathematicians admitted difficulty in understanding his thesis, reporters, with Dean George D. Birkhoff, Harvard mathematician, as interpreter, were able to comprehend his new mathematical concepts and explain them to their readers. With these concepts Professor Cartan has evolved a new system of mathematics which may prove to be a bridge between the universe and the atom, the "missing link" in the arithmetical chain by which it is hoped to reconcile ordinary concepts of space with the theory of relativity. Known as "non-affine geometries," Cartan's system is based on the theory that spinors do not always behave like tensors, that they are occasionally "bivalent" and belong both in Euclidian and general geometry. It is Cartan's modest hope that this dual personality of spinors may simplify the eventual reconciliation between some of the time-space measurements of Einstein and the timeless planes of ancient geometricians who lived in a stationary and unchanging world.

Another radically different and possibly more abstruse mathematical system was outlined by Professor Rudolf Carnap, of the Deutsche Universität, Prague. Typical of recent breaks with old traditions and the introduction of new logic in every field of knowledge, it is based on an infinite rather than a finite number of premises. Its chief advantage is that it is far more complete than older systems, even the best of which permitted the writing of unprovable arithmetical

From Professor Leonard E.

Dickson, of the University of Chicago, the conference heard a formula for the solution of Waring's problem which has baffled mathematicians since the Middle Ages, and with it further proof of the inherent rhythm of numbers

As the conference turned from mathematics to astronomy the paper of Professor Tullio Levi-Civita, of the University of Rome, extended Einstein's relativity theory with a more precise definition of the fundamental law of the universe and thus became one of the most significant in either of the two fields it embraced His theory, dealing with the gravitational fields of two bodies rather than only one, is expected to be a focal point for mathematical and astronomical research during the next few years

Discovery of a new red nebula, really a cosmic dust cloud shining with the reflected light from nearby Antares, was reported by Dr. Otto Struve, of the Yerkes Observatory, and is also expected to form the basis of much future research. From Dr. Struve's co-workers came announcement of cold and dim "ghost stars," hitherto undetected. While astronomers debated over possible temperatures and sizes of these stars, Professor Henry Norris Russell, of Princeton, and Professor Antonie Pannekoek, of Amsterdam, explained new and improved methods they have developed for determining stellar masses and temperatures.

From Sir Arthur Eddington, seeking to link relativity and the quantum theory, astronomers heard the charge that both are too artificial Sir Arthur also reported what he terms "the cosmical number"-- 2 136 2^{256}—which he believes is the number of particles in the universe Turning to the sun, he fixed its interior temperature as 18,000,000 degrees Fahrenheit, described its center

MEMBERS OF THE CONFERENCE ON THE STEPS OF MEMORIAL HALL

AFTER ONE OF THE ADDRESSES AT THE INTRODUCTORY MEETING ON "THE FACTORS DETERMINING HUMAN BEHAVIOR."

as an inferno of x-rays and tiny particles streaking about at speeds ranging from 40 to 10,000 miles per second. Crowded together in a cubic centimeter, he said, there are more than a quadrillion atoms, about twice as many free electrons and 20,600 trillion x-rays.

In another section of the symposium on the physical sciences, nuclear physicists heard Professor Merle A. Tuve, of the Carnegie Institution, relate the discovery of a super-powerful cosmic force sealed in the very hearts of the atoms of which all matter is composed. Far stronger than any force previously known to science, it is believed to function as a sort of "cosmic cement" holding the tiny particles in the heart of the atom—and with it the universe—together. According to Professor Gregory Breit, of the University of Wisconsin, the force is a million times stronger than gravitation. It appears when two atomic particles approach within 28 trillionths of a centimeter of each other, at which point its force is more than 11,000,000 volts of electricity—more than double the highest voltage man has been able to create in the laboratory. An allied section on cosmic radiation constituted the arena in which two of the world's outstanding authorities in that field, Professor Arthur H. Compton, of Chicago, and Professor Robert A. Millikan, of the California Institute of Technology, renewed their debate as to whether the primary radiation is composed mainly of uncharged energy bullets, photons or charged particles. Most promising of solving the riddle was a theory advanced by Dr. W. F. G. Swann, of the Franklin Institute, which, substantiating Dr. Compton's beliefs, mathematically eliminated photons as necessary constituents of the primary radiation.

Steps in the growth of mountains, how the seas of molten rock rose from the subterranean depths and were pressed into shape between the crushing jaws of the earth, were discussed before the geology section of the physical science symposium. Professor Edward B. Bailey, of the University of Glasgow, told of the crumpling and rafting together of layers of mud, sand and gravel in huge basins and traced the gigantic movements of the earth's crust which folded these formations and lifted the whole mass above the surface to form mountains. How these massive ranges float on the earth just as an iceberg floats in water, was outlined by Professor Andrew C. Lawson, of the University of California, while Dr. Norman L. Bowen, of the Carnegie Institution, reported thirty years' observation of miniature volcanoes he has created in his laboratory.

Sawdust and other scraps of waste wood can be converted into the three fundamental elements of the human diet, inexpensively and on a scale to feed an army, Dr. Friedrich Bergius, the well-known German industrial chemist, told the conference. Providing the elements of a balanced diet—carbohydrates, proteins and fats—the process is one of the greatest strides toward a nation's self-sufficiency and economic independence in recent years. An outstanding departure from earlier technically successful, but economically impracticable processes is Dr. Bergius's use of concentrated hydrochloric acid as a converting agent, enabled by the design of equipment capable of withstanding the acid's highly corrosive action. It was not reported how the stumbling block of earlier attempts had been overcome except that ordinary metal containers were lined with "a special ceramic material."

Another important development reported before the chemical section was the announcement by Dr. Hans Fischer, of Munich, that hemin, the red coloring matter of blood so essential to life, and chlorophyll, green matter vital in the

—*Photograph from the Boston Traveler*

SIR ARTHUR STANLEY EDDINGTON

PROFESSOR OF ASTRONOMY AND DIRECTOR OF THE OBSERVATORY AT THE UNIVERSITY OF CAMBRIDGE.

physiology of plants, have strikingly similar nuclei. Already awarded the Nobel prize for his synthesis of hemin, Dr. Fischer is now essaying the synthesis of chlorophyll. Other attempts at the synthetic production of life substances were reported by Dr. Leopold Ruzicka, of Zurich, who has succeeded in compounding artificial male sex hormones. One he synthesized is five times as potent as the corresponding one found in nature.

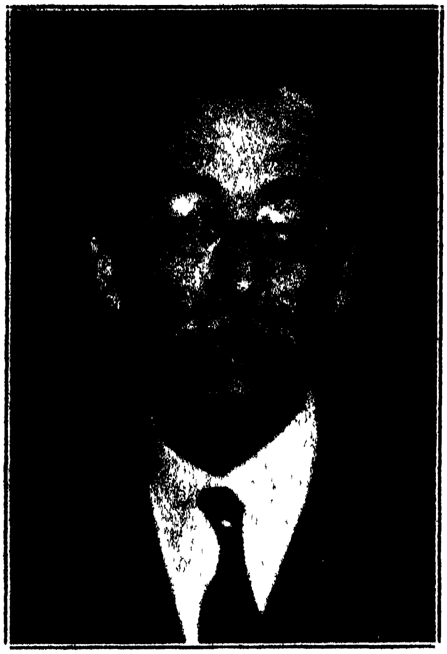
Diabetes as a disturbance not only of one gland, the pancreas, but of several other glands, was discussed by Professor Bernardo A. Houssay, of the University of Buenos Aires. While the pancreas is important in that it produces insulin, he said, the liver, where sugar is manufactured, and the thyroid, the pituitary and the cortex of the adrenal gland which control sugar content of the body, are also important. Only when the complex interrelations between these glands and the varied effects of their interacting secretions are fully understood, he stated, can progress be made toward the cure of diabetes.

Proof that formation of the automatic nervous system is among the earliest developments in embryos was reported by Sir Joseph Barcroft, of the University of Cambridge, who took unique moving pictures of the early breathing movements of unborn sheep in the first stages of prenatal development. Breathing, he found, is due to the rhythmic activity of the central nervous system. Two other pieces of the jig-saw puzzle of prenatal growth were contributed by Professor Ross G. Harrison, of Yale, and Professor Hans Spemann, of the University of Freiburg. Professor Harrison has formulated a theory of polarity for application to animal life. Under its tenets all tissue has a positive and a negative pole, ac-

—*Photograph from the Boston Post*

DR. FRIEDRICH BERGIUS

PROFESSOR OF CHEMISTRY AT HEIDELBERG UNIVERSITY.



MASAHARU ANESAKI

PROFESSOR OF THE SCIENCE OF RELIGION AND THE HISTORY OF RELIGION, EMERITUS, AT THE IMPERIAL UNIVERSITY OF TOKYO, JAPAN

quired very early in its development to determine its symmetrical placement in the embryo. Professor Spemann has found that, as the embryo develops, a set of chemical "organizers" takes over the task of directing growth, timing and regulating the proper formation of arms, legs, the head and other parts of the body He has found where these organizers are, when they are called into play and how they act. Only their exact chemical nature remains a secret and Professor Spemann is now attacking that aspect of the problem.

Another great stride toward unraveling the mystery that veils body processes was taken by Dr. John H. Northrop, of the Rockefeller Institute, who reported research on enzymes, those extraordinary substances within the living organism which control the rate of its reactions. Isolating a whole series of these enzymes and crystallizing them, he has found they are proteins with chemical characteristics as clear-cut and definite as other protein molecules. So close is the relation, in fact, that he has been able to compound several active enzymes from inert proteins. In some cases the conversion is autocatalytic, some enzymes having the power to form themselves from inert proteins. Dr Northrop has also conducted research in that twilight realm of being inhabited by the filterable viruses, cause of such dread diseases as infantile paralysis, and bacteriophage, the "eater of bacteria," which saved so many lives during the world war The formation of bacteriophage, he said, is a special case of autocatalysis, and although he has not isolated this substance yet, he has been able to concentrate it in a very pure form

Other speakers before the biological

—*Photograph from the Boston Traveler*

HU SHIH

PROFESSOR OF CHINESE PHILOSOPHY AT THE NATIONAL UNIVERSITY OF PEIPING, CHINA symposium were Sir Frederick G. Hopkins, of the University of Cambridge, who traced the influence of chemistry on biological thought; Professor Filippo Silvestri, of the Royal College of Agriculture, Portici, who discussed the phenomena of multiple birth in the insect world; Professor Elmer Drew Merrill, of Harvard, who spoke of plants as indicators of civilizations; Professor Johan Hjort, of Oslo, who examined the biological processes of whales, Dr. Karl Landsteiner, of the Rockefeller Institute, who described the interrelation of allergy, immunity and anaphylaxis; Dr. Kiyoshi Shiga, of Kitasato Institute, Tokyo, discoverer of the dysentery bacillus, who related recent progress in the fight against that disease; Professor August Krogh, of Copenhagen, who reported the use of isotopes for detecting the transfer of chemical substances within the living organism, and Professor The Svedberg, of the University of Upsala, who described the great size and shape of the protein molecule, building blocks of all living tissue.

Additional speakers before the symposium in the physical sciences were Professor Ronald A. Fisher, of the University of London, who discussed uncertain inference; Professor Godfrey H Hardy, of the University of Cambridge, who outlined the work of the Indian mathematician, Ramanujan; Dr. Theodore Dunham, of the Mount Wilson Observatory; Professor Megh nad Saha, of the University of Allahabad; Professor Arthur Haas, of the University of Vienna; Professor Howard P. Robertson, of Princeton; Professor Manuel S Vallarta, of the Massachusetts Institute of Technology; Dr. J. C. Street, Harvard; Dr. Eugene Feenberg, University of Wisconsin; Professor Eugene P. Wigner, Princeton; Professor J. Robert Oppenheimer, University of California; Professor John H. Van Vleck, Harvard; Professor Arthur J. Dempster, Chicago; Professor Walker Bleakney, Princeton; Professor Otto Stern, Carnegie Institute of Technology; Professor I. I. Rabi, Columbia; Professor John R. Dunning, Columbia; Professor K. T Bainbridge, Harvard; Dr Frank B. Jewett, of the Bell Telephone Laboratories; Professor William B. Scott, of Princeton, and Professor Peter Debye, of the University of Leipzig.

Speakers in the two symposia in the humanities were: "Authority and the Individual". Professor Wesley C. Mitchell, Columbia; Professor Dennis H. Robertson, the University of Cambridge; Professor Douglas B. Copeland, the University of Melbourne; Professor William E Rappard, University of Geneva; Professor John H. Clapham, University of Cambridge; Professor Robert M MacIver, Columbia; Professor Charles McL. Andrews, Yale; Professor John Dewey, Columbia; Professor Edward S. Corwin, Princeton; Professor Hans Kelsen, Geneva; Professor Werner Jaeger, University of Berlin; Professor Corrado Gini, University of Rome; Professor Friedrich Meinecke, University of Berlin; Professor Paul Hazard, Collège de France; Professor Howard M. Jones, Michigan; Professor Edward J. Dent, University of Cambridge; "Independence, Convergence and Borrowing in Institutions, Thought and Art": Professor Vere G. Childe, University of Edinburgh; Professor Michael I. Rostovtzeff, Yale; Professor Eduard Norden, University of Berlin; Professor Leopold Wenger, University of Vienna; Professor Rene Maunier, University of Paris; Professor Louis Ginzberg, Jewish Theological Seminary of America; Professor Charles H. Dodd, University of Cambridge; Professor Frederick M. Powicke, University of Oxford; Professor Henry O. Taylor, New York; Professor Adolph Goldschmidt, University of Berlin; Professor Joseph Bedier, Collège de France;

—*Photograph from the Boston Traveler*

DR. ANTONIE PANNEKOEK

PROFESSOR OF ASTRONOMY AT THE UNIVERSITY OF AMSTERDAM, AND MRS. PANNEKOEK.

Professor Etienne Gilson, Collège de France; Professor Hu Shih, National University of Peiping; Professor Masaharu Anesaki, Imperial University of Tokyo; Professor Paul Pelliot, Collège de France.

From these four symposia the framework for the fifth and final symposium, "Factors Determining Human Behavior," was constructed. The chemical, physiological, historical, social, political, psychological and cultural influence on man and his actions, all were examined in this climactic and panoramic discussion. It was not expected that the symposium would give the final answer to the questions involved, but that each speaker would point out some aspect which he had studied. Thus from the discussion as a whole it would be possible to gain at least some conception of the complexity of the problem and of the important advances that have been made in recognizing influences other than pure reason on man's conduct. That this purpose was realized is indicated by the wide variety of factors which the eight participating scholars presented for consideration.

To psychologist Charles G. Jung, of Zurich, hunger is the most potent urge influencing mankind, irrespective of the opinion of his great rival Freud, that sex is the most powerful factor. Sex, however, is second, according to Professor Jung, and then come the drive to activity, the urge to reflection and the creative urge. To physiologist Edgar D. Adrian, of the University of Cambridge, tracing the influence of the nervous system, a larger brain would make man better behaved. With a brain twice its present size, man's behavior would be superhuman, he said. Dr. James B. Collip, McGill biochemist, named the pituitary gland as having tremendous influence on man's behavior, although he declared other glands and various other organs have additional effects. Another psychologist, Dr. Pierre M. F. Janet, of the Collège de France, cited nervous exhaustion as a factor, terming it one of mankind's greatest liabilities. A third psychologist, Professor Jean Piaget, of the University of Geneva, urged the study of the development of the infant mind as a measure whereby the development of man's mind could be determined. Philosopher Carnap emphasized how passions often outweigh reason and warned that logic must take into account the illogical. From Dr. A. Lawrence Lowell, president emeritus of Harvard, came an example from history as evidence of how men, like animals, may attain a consistent and harmonious method of conducting their affairs, although the result may be the exact opposite of their preconceived ideas. The concluding speaker, anthropologist Bronislaw Malinowski, of the

—Photograph from the Boston Post

PROFESSOR PIERRE MARIE FELIX JANET

PROFESSOR OF PSYCHOLOGY, COLLÈGE DE FRANCE, AND MME. JANET.

—*Photograph from the Boston Traveler*

ARTHUR HOLLY COMPTON, PROFESSOR OF PHYSICS AT THE UNIVERSITY OF CHICAGO, AND DR. KARL TAYLOR COMPTON, PRESIDENT OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

University of London, traced the broad influence exerted by varying cultures.

Perhaps one of the most significant results of the conference came from a symposium not on the official program, yet conducted with the cooperation of Harvard University and four renowned scholars who participated in the conference. Dr. Dewey, America's outstanding philosopher; Dr. Gilson, distinguished French historian; Dr. Malinowski and Dr. Hu, one of China's leading thinkers. In a special interview these men were asked to summarize the net results of the academic sessions by several members of the National Association of Science Writers who had reported the meetings. With the exception of Dr. Hu, who approved its purpose, but doubted its efficacy, all agreed that the conference might well form the basis for a permanent international supreme court of organized knowledge, dedicated to the intelligent guidance of humanity in the solution of practical world problems.

WESLEY FULLER

THE SCIENTIFIC MONTHLY

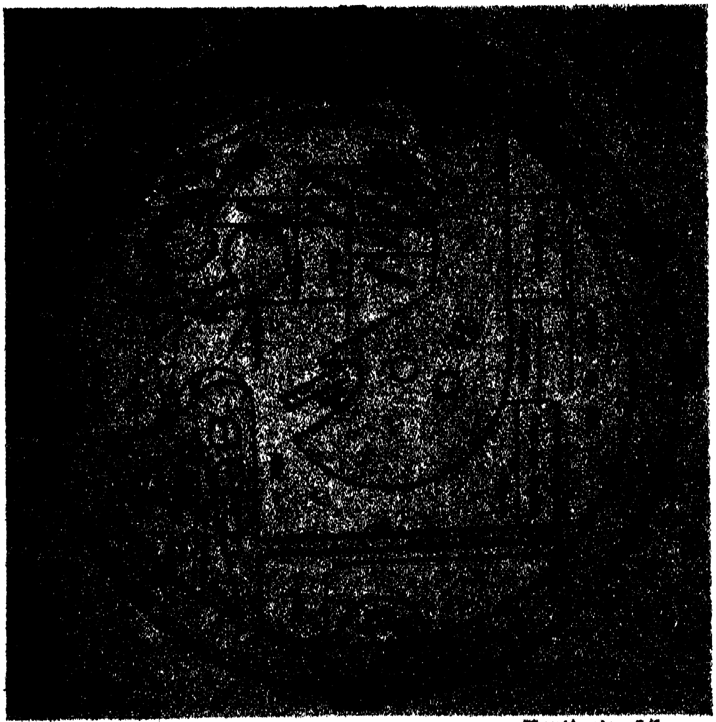
DECEMBER, 1936

THE PRESENT STATUS OF COSMOLOGY[1]

By Professor **RICHARD C. TOLMAN**

THE CALIFORNIA INSTITUTE OF TECHNOLOGY

THIS article attempts to give a qualitative account of the present status of cosmology. I wish to begin by raising objections to my own title, on account of the inclusion of that very dangerous term, "cosmology." It is a word which has a long background of dubious metaphysical association, and seems to imply the treatment of the whole universe as a unit, by some method which far transcends the limitations of ordinary observation. But a knowledge of the *whole* universe is certainly given to no man, and its treatment as an understood *unit* is possible to no man—not even to a philosopher. Whatever philosophers may



Huntington Library.

FIG. 1. HAWQUAL'S MAP OF THE WORLD AS RECONSTRUCTED BY J. T. REINAUD.

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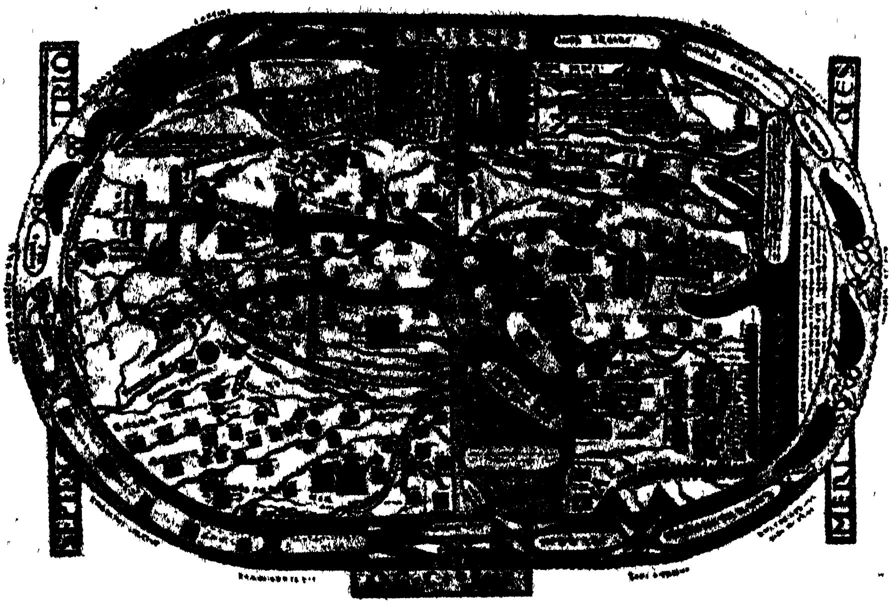
[1] Adapted from the presidential address to the Pacific Division of the American Association for the Advancement of Science, June 17, 1936.



Huntington Library

FIG. 2. MAP OF THE WORLD ACCORDING TO BEAUTUS.

do, and indeed I think should do, it seems imperative that those of us who are scientists should write only on subjects concerning which we have specific observational knowledge. Hence for the purposes of this article I shall ask you to regard the word "cosmology" as quite a modest one, implying the study and scientific treatment of our physical surroundings, out as far as our telescopes have penetrated, with only the most guarded extrapolation to further distances or to matters that we have not yet observed.

With this meaning of the word, it is evident that cosmology will be a continually growing branch of science, passing through different stages of development as we obtain the possibility of observing more and more distant astronomical objects. I have provided a number of illustrations to denote these different stages in the development of ideas as to cosmology and to show the nature of the different astronomical objects which we have been able to observe. These latter range all the way from our own moon, which is the nearest of all, to the distant nebulae which lie far beyond the stars in our own milky way or galaxy. The illustrations come from several sources, including two from the Huntington Library, but most of them have come from the Mount Wilson Observatory, where I have had the kind and expert advice of Dr. Hubble in making selections.

THE COSMOLOGY OF A FLAT EARTH

In very ancient days, before the science of the Greeks, the knowledge of man was closely limited by his immediate surroundings. His ideas of cosmology were self-centered and, so to say, parochial. The world consisted of his own country, large and important, surrounded by other lands of lesser size and value, and all in turn surrounded by an unknown ocean. The earth was flat, mariners should keep near shore lest they fall over the edge, and the sun, moon and stars rose from beyond the ocean to give us a light by day and by night, and sank again to return under the earth ready for the start of a new journey.

Such ideas, still possible for backward folk, persisted for most men long after there was a good scientific tradition to the contrary, and I have secured two ancient maps of the world to illustrate this stage of cosmology—one a Moslem map first drawn in the tenth century by a traveler from Bagdad named Quasim Muhammad Ibn Hawqual—the other a Christian map first drawn in the eighth century by a priest of the name Beautus Libaniensis.

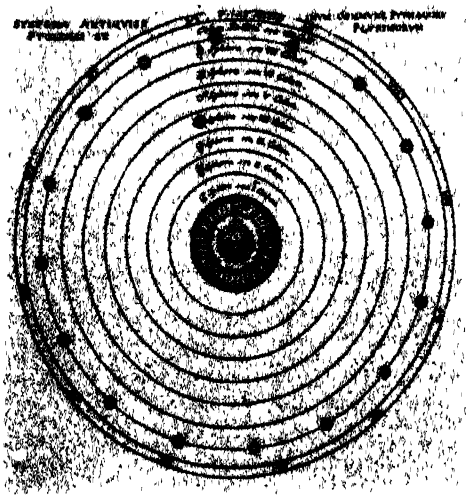


FIG. 3. OLD CUT ILLUSTRATING PTOLEMAIC SYSTEM.

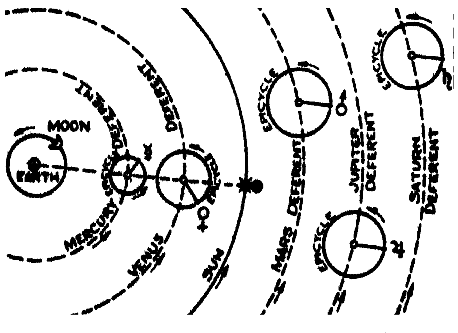


FIG. 4. PTOLEMAIC SYSTEM.
SIZE OF ORBITS ARBITRARY.

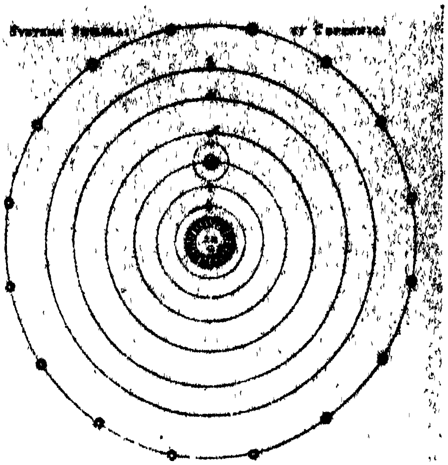


FIG 5. OLD CUT ILLUSTRATING COPERNICAN SYSTEM.

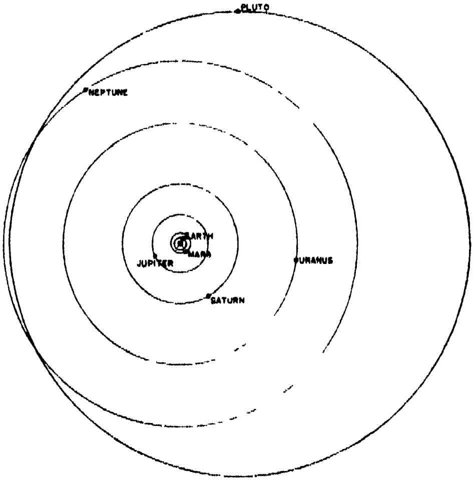


FIG. 6. THE SOLAR SYSTEM
DRAWN TO SCALE WITH THE POSITIONS OF THE PLANETS AS OF JANUARY, 1936.

My first illustration, Fig. 1, gives the map of the whole world as it seemed to the Bagdad geographer Hawqual. The lettering has been put in at a later time in French, north lying as you see to the left, and south to the right. The Moslem influence is evident in the highly geometrical character of the contours. The curved horn to the south—that is, to the right—is the continent of Africa; the straight wide Nile flows into the Mediter-

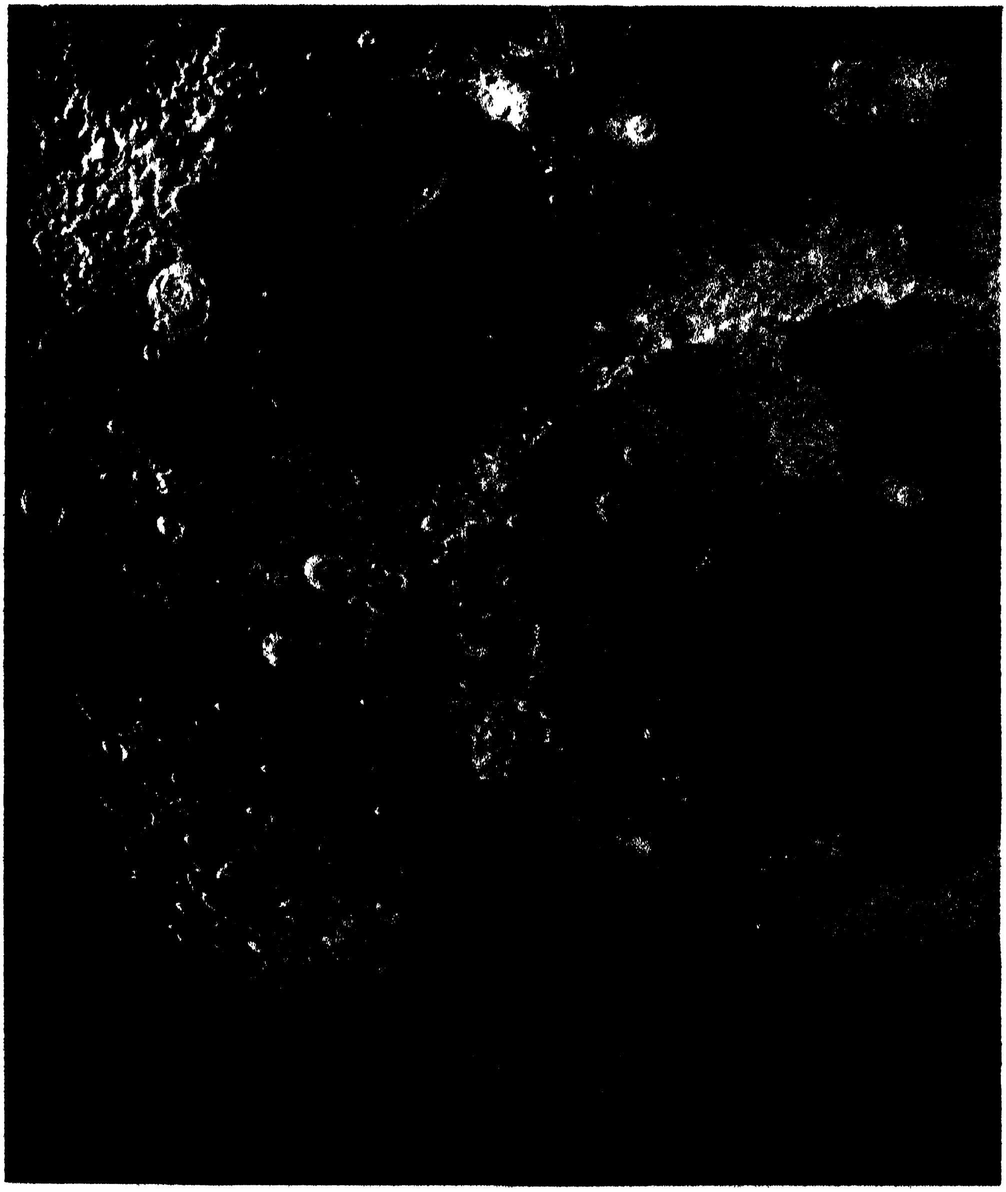


FIG. 7. NORTHERN PORTION OF MOON,
AGE 18 DAYS, TAKEN AUGUST 7, 1925, WITH THE MOUNT WILSON 100-INCH REFLECTOR.

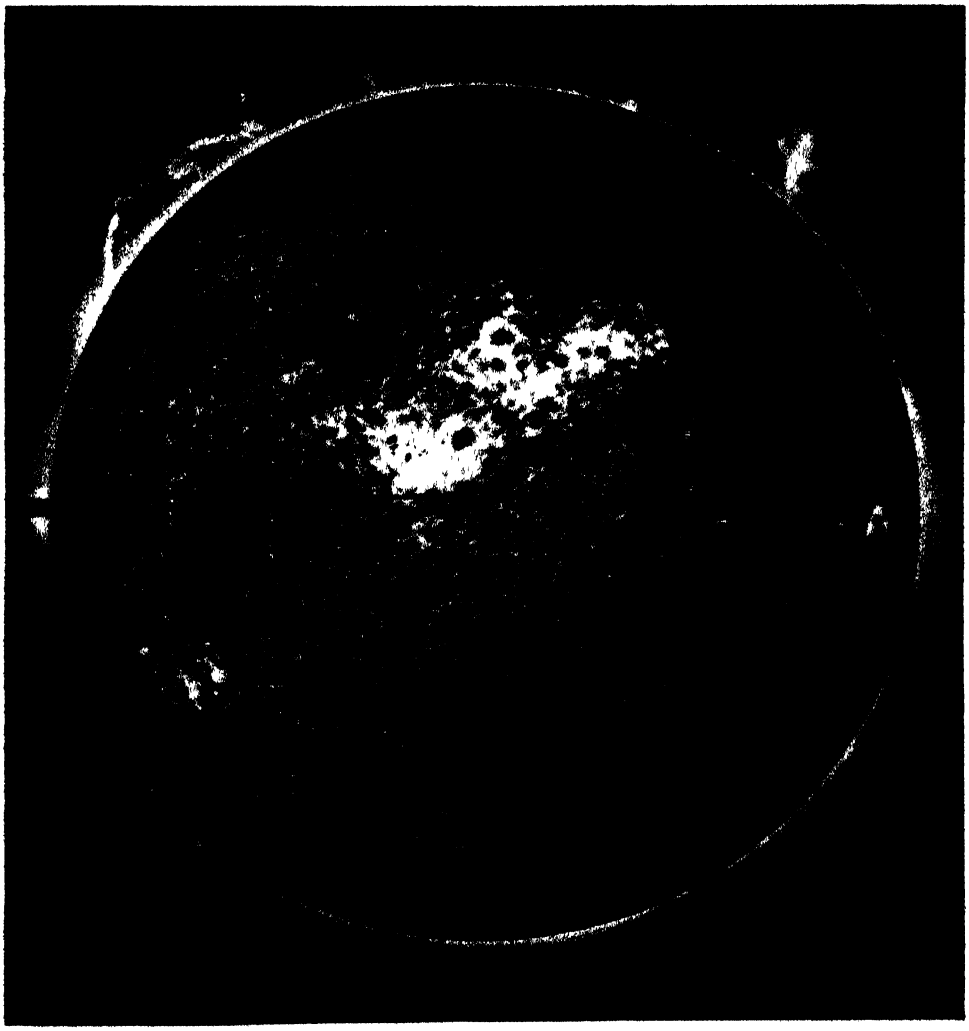


FIG. 8. SURFACE OF SUN

TAKEN AT MOUNT WILSON WITH THE LIGHT FROM CALCIUM ATOMS.

ranean—with three round islands, Cyprus, Crete and Malta. The parochial point of view is indicated by the great extent of Moslem countries on the Indian Ocean and Gulf of Persia, with little Europe and the empire of China crowded to the west and east. This point of view was also expressed in Hawqual's writings:

> I have described the earth in its length and breadth; I have given a view of the Moslem provinces; but have taken no account of the division by climates, in order to avoid confusion . . . in a word, I have collected all that has ever made geography of interest either to princes or peoples. I have not described the country of the African blacks and the other peoples of the torrid zone; because naturally loving wisdom, ingenuity, religion, justice, and regular government, how could I notice such people as these, or magnify them by inserting an account of their countries?

The second illustration, Fig. 2, shows the whole world as it appeared to the monk Beautus, again with north to the left and south to the right, and again with all the lands of the earth surrounded by the unknown ocean, this time taken as filled with mythical islands, many fish and some quite strange-looking rowboats. The local point of view is now shown by the great size ascribed to Europe with its houses and churches; and the Christian influence is made evident by the Garden of Eden, where you can see Eve just picking the apple from the tree of knowledge to give to an eager Adam.

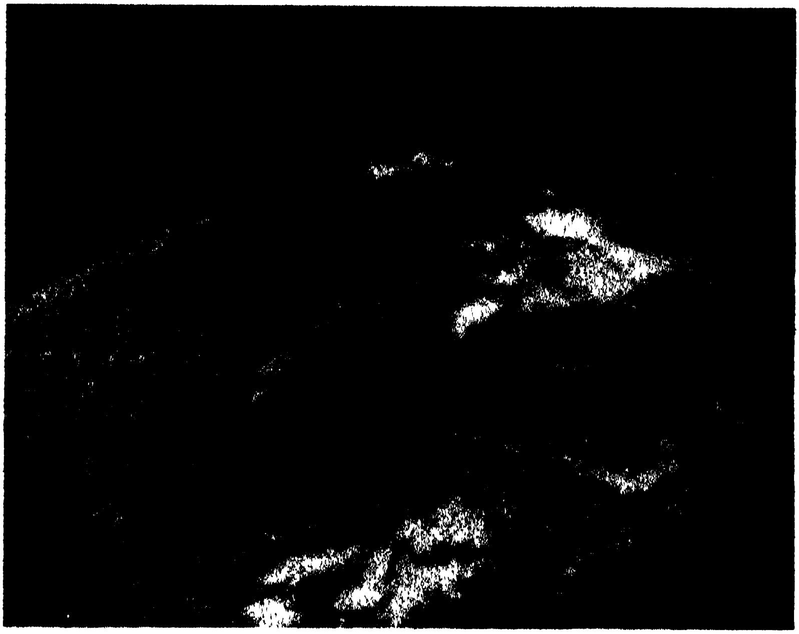


FIG 9. SURFACE OF SUN

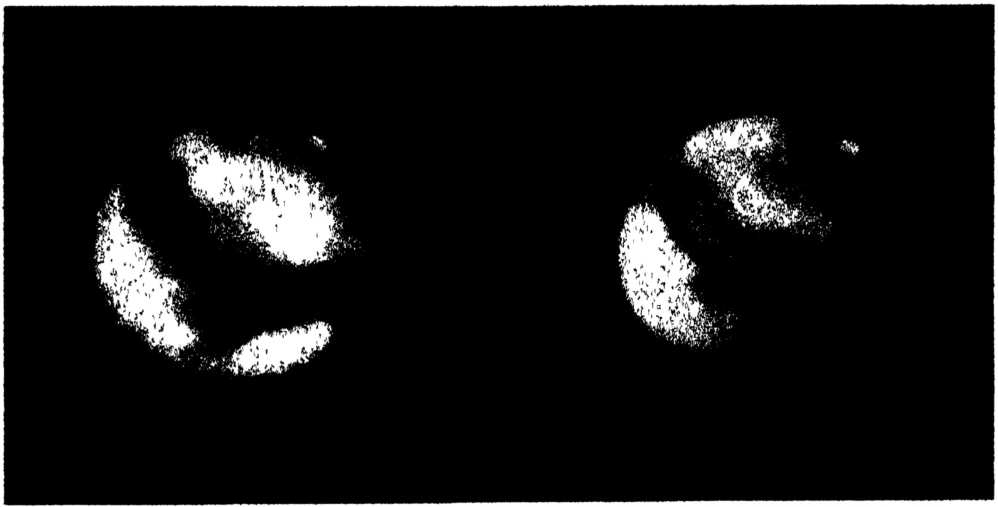
TAKEN AT MOUNT WILSON WITH THE LIGHT FROM HYDROGEN ATOMS.

THE PTOLEMAIC SYSTEM

These maps of a flat earth represent a very early stage of cosmology, but long before these particular maps were drawn the science and philosophy of the Greeks had led to much more acceptable ideas. These ideas were presented with great detail and completeness about the year A.D 140 by the Alexandrian mathematician, geographer and astronomer, Ptolemy; and for fourteen centuries the Ptolemaic system, as described in his great book, the Almagest, provided the accepted cosmology of the really learned.

I have taken a cut, Fig. 3, from an English book of the time of Charles the Second to illustrate the Ptolemaic stage of cosmology I am a little hesitant about introducing it, because the old drawing does not give a true impression of those satisfactory scientific features which were successfully treated by Ptolemy. At the center of the system is the earth, recognized by Ptolemy to be a sphere of land and water of somewhere near its true size. Outside the earth are spheres of air and fire, in accordance with the Greek philosophy as to the behavior of earth, air, fire and water, and outside these are the heavenly bodies moving in great circles—the moon, Mercury, Venus, the sun, Mars, Jupiter and Saturn, and finally the stars of the firmament in the order named.

For Ptolemy the earth was at rest and



Mount Wilson Observatory.

FIG. 10. PHOTOGRAPHS OF MARS.

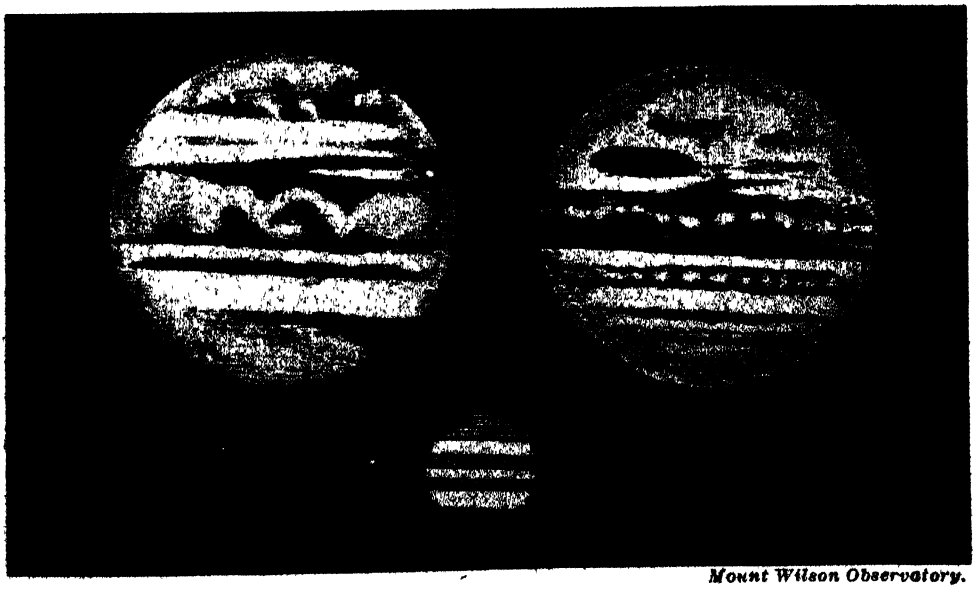


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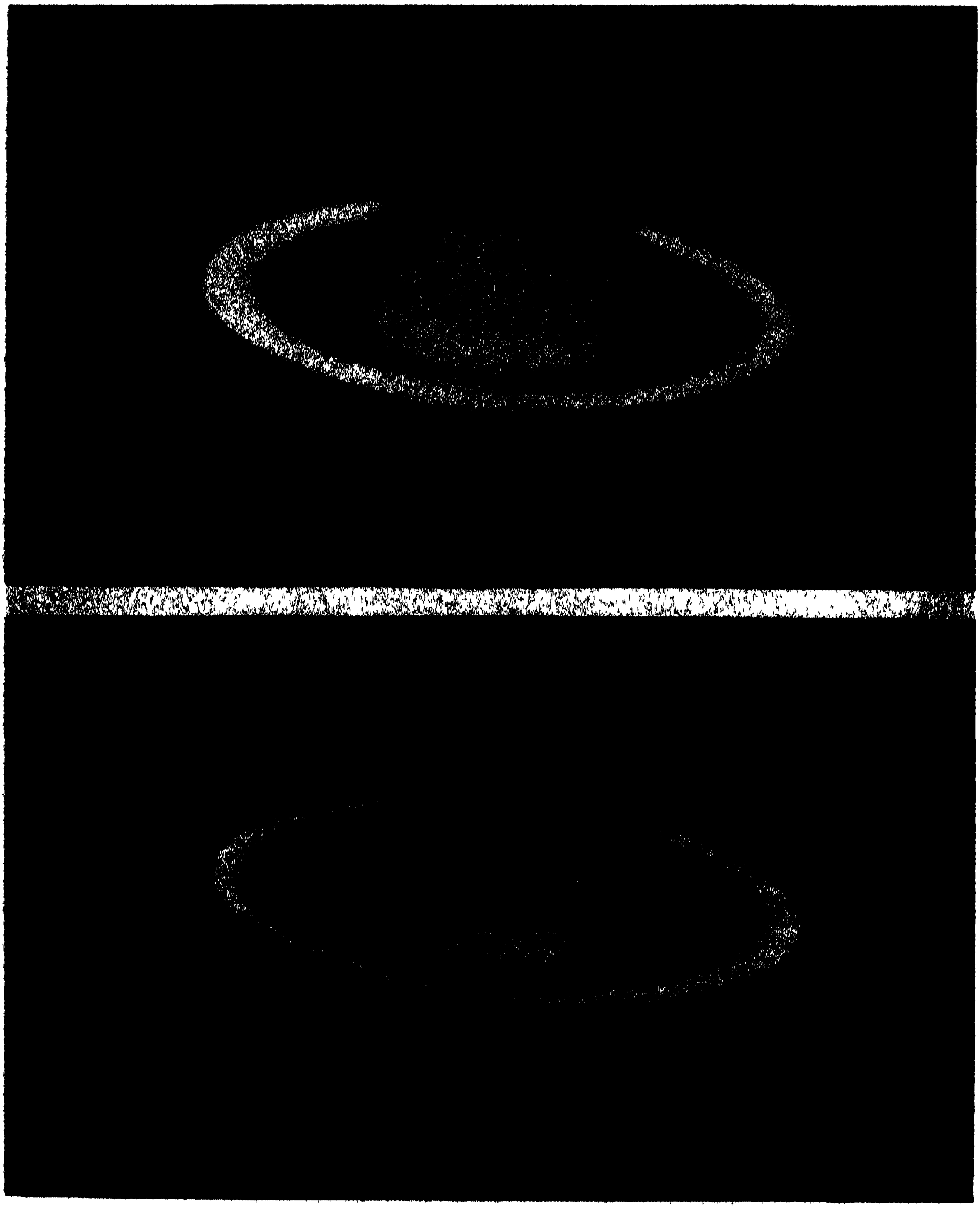
FIG. 11. DRAWINGS OF JUPITER.



Mount Wilson Observatory.

FIG. 12. PHOTOGRAPHS OF SATURN.

Mount Wilson Observatory.

FIG. 13. PHOTOGRAPH OF HALLEY'S COMET.

FIG. 14. MODEL OF THE GALAXY

FROM THE HALLEY LECTURE DELIVERED ON JUNE 5, 1935, BY J S. PLASKETT.

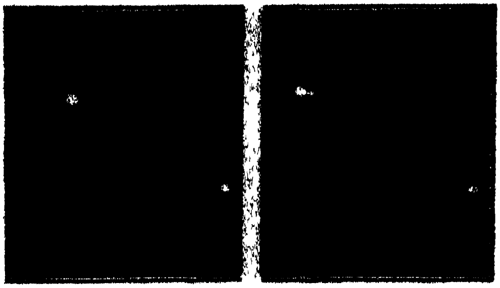


FIG 15 THE TRIPLE STAR KRÜGER 60 TWO PHOTOGRAPHS, FIVE YEARS APART, MADE BY BARNARD AT THE YERKES OBSERVATORY.

at the center of things, and the rising and setting of the sun, moon and stars was due to the revolution of the whole heavens around the earth once every twenty-four hours. In addition to this rapid daily revolution there was a further slow motion in great circles called "deferents," and in small circles called "epicycles," as shown by the somewhat more scientific looking diagram, Fig. 4; and these combined motions gave a very fair account of actual observations.

It seems to us now that Ptolemy was very local minded in making our own earth so important, so central and so fixed. Nevertheless, from a phenomenological point of view his system did describe his observations, and from a modern theoretical point of view, that of Einstein's general relativity of motion, we do not characterize Ptolemy's mode of approach as wrong but merely as very inconvenient and extremely complicated

THE COPERNICAN SYSTEM

The learned world had to wait a long time, nevertheless, before it was ready for intellectual clarity and simplicity. The idea that man's earth was not the center of all things seemed altogether too contrary to common sense, to human importance and to revealed religion. Finally, however, in the year 1543 the publication of the great work of Copernicus, "On the Revolution of the Heavenly Bodies," gave that exhaustive treatment necessary for the change to a new point of view.

Fig. 5, also from the time of Charles

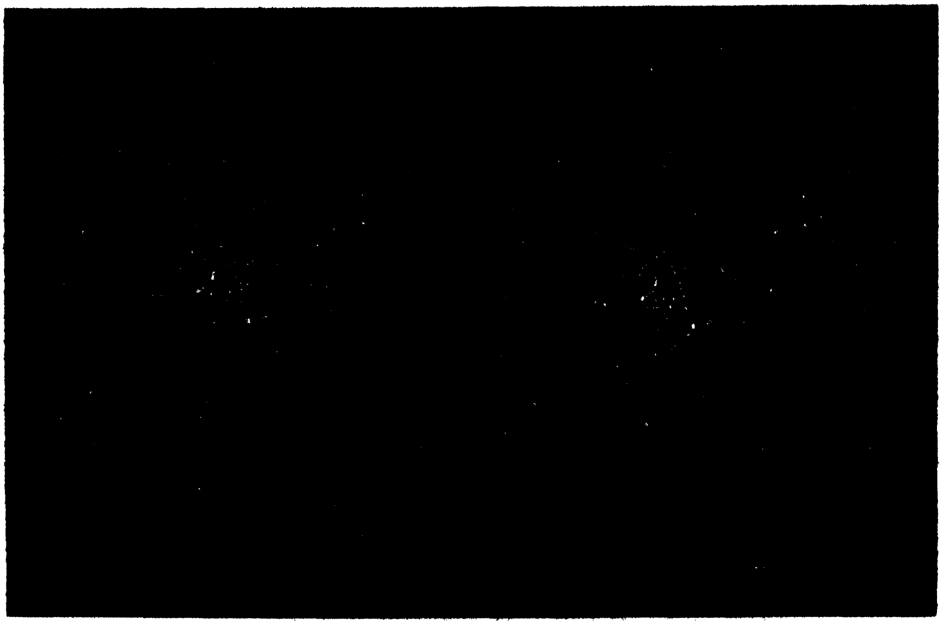


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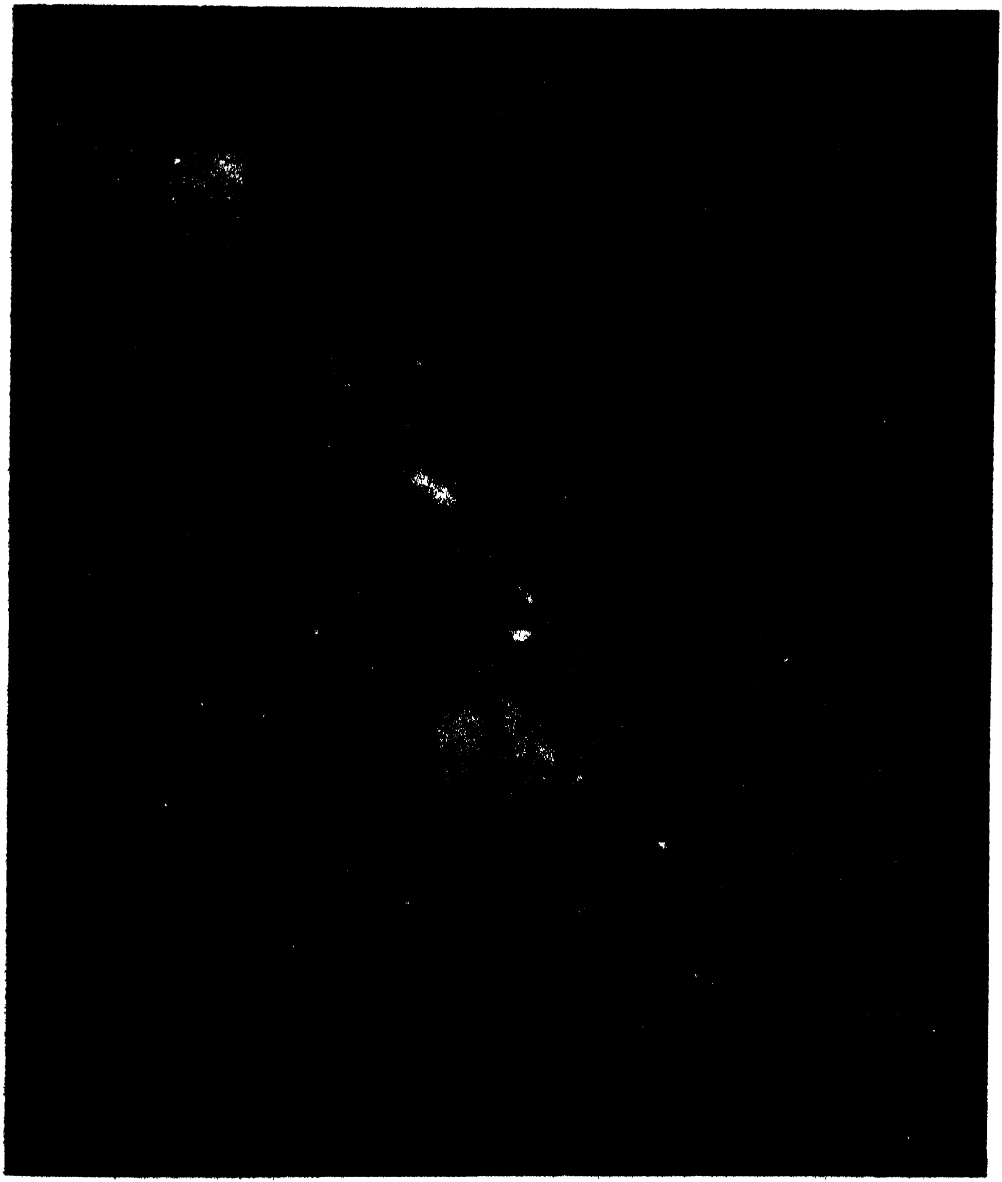
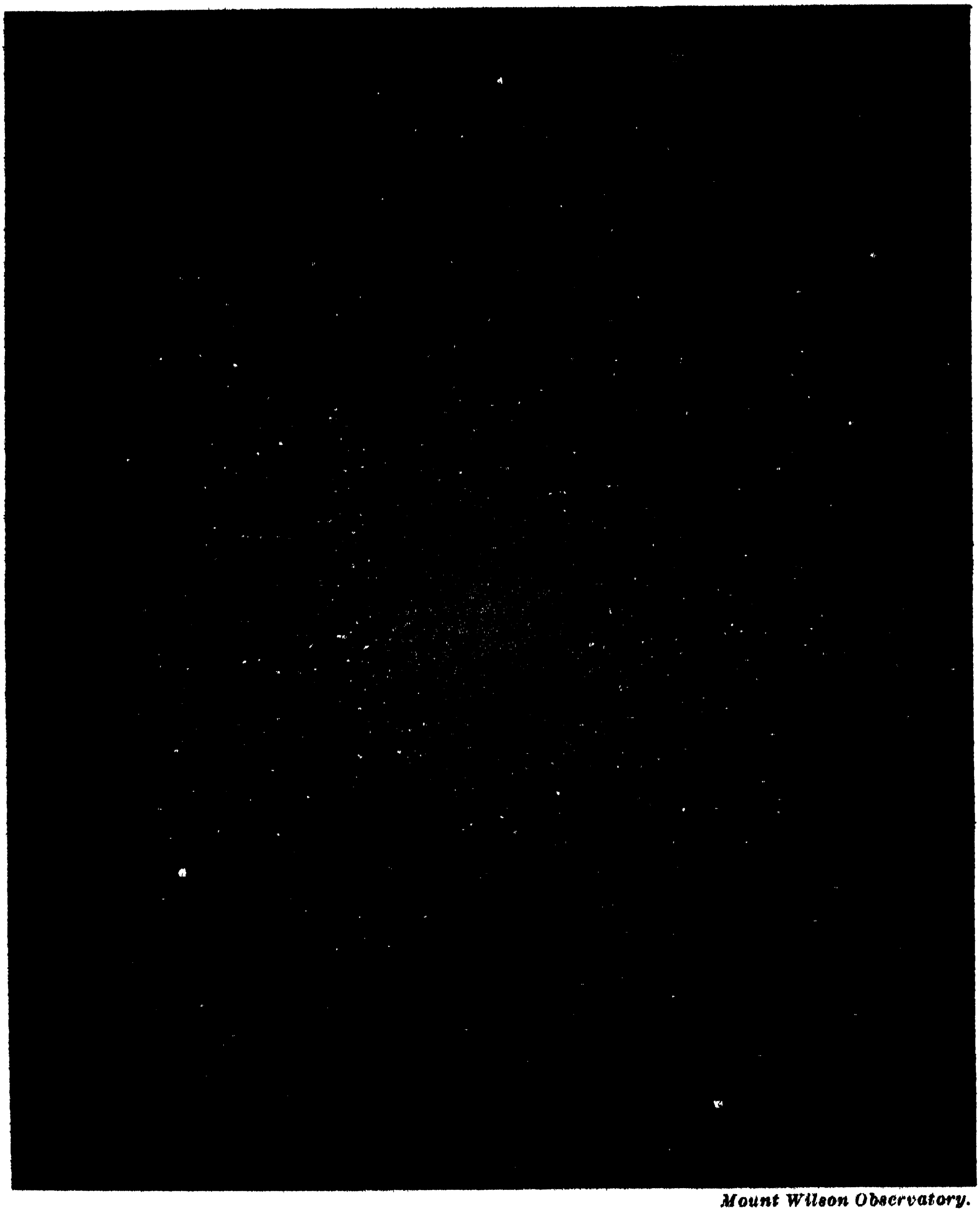
FIG. 16. TWO DIFFERENT EXPOSURES OF OPEN CLUSTER OF STARS, MESSIER, 35.



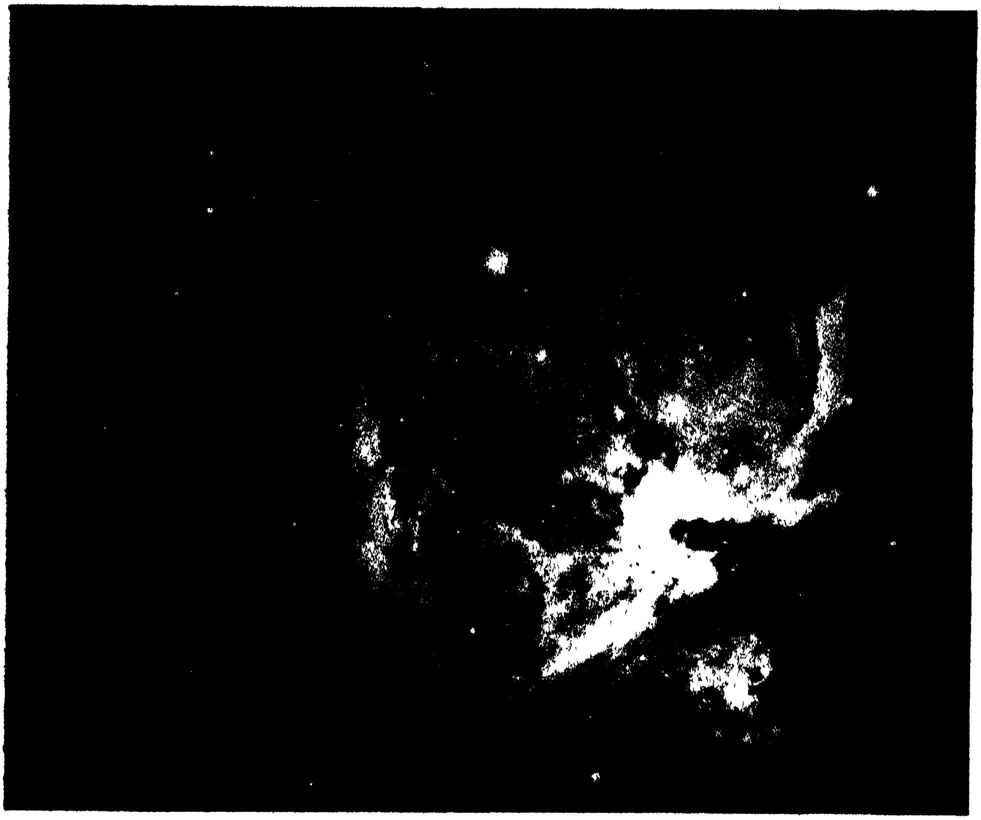
Mount Wilson Observatory.

FIG. 17. STAR CLOUDS IN SAGITTARIUS.



Mount Wilson Observatory.

FIG. 18. GLOBULAR CLUSTER OF STARS, MESSIER 3.



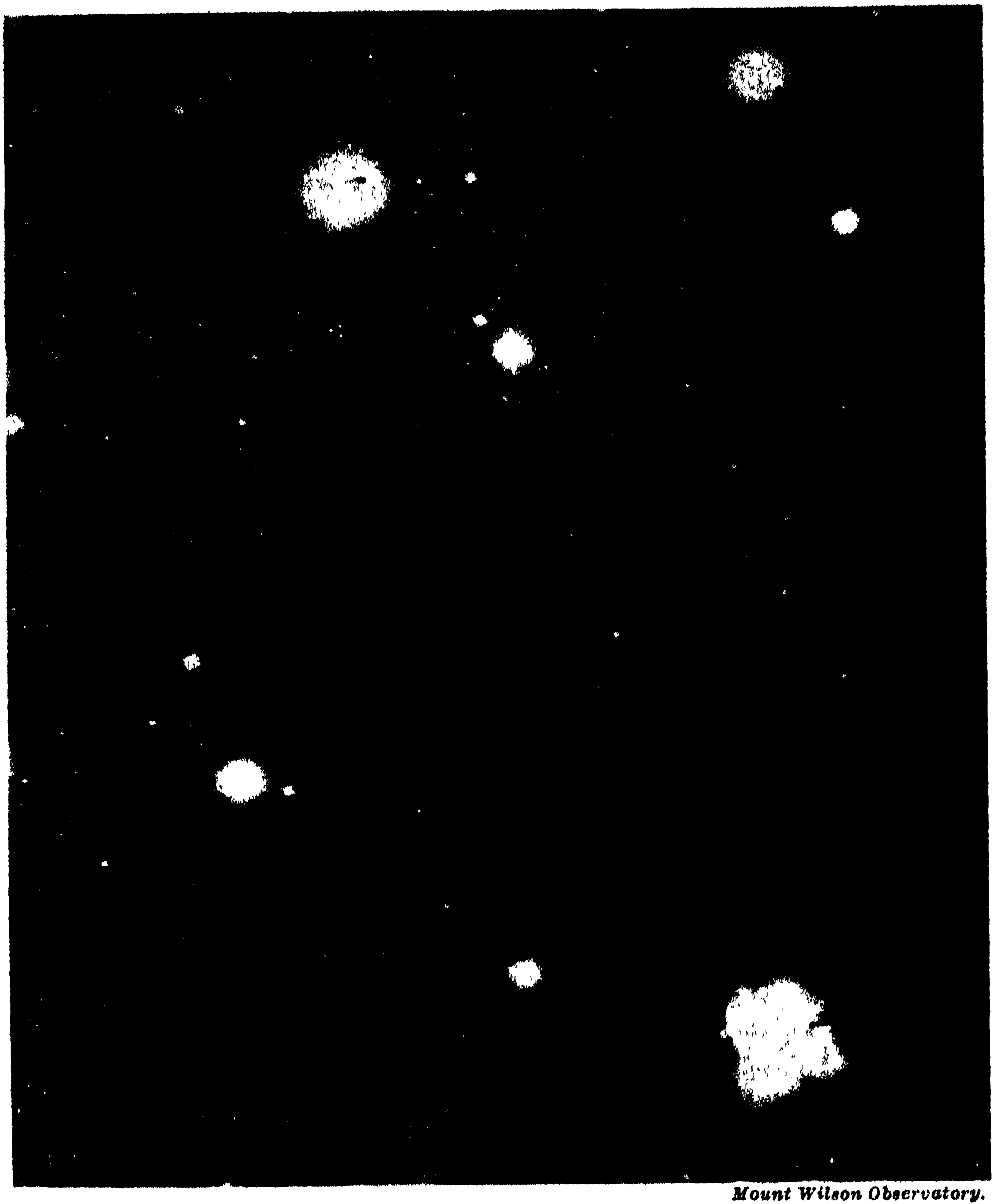
Mount Wilson Observatory.

FIG. 19. ILLUMINATED MATERIAL IN ORION.

THREE HOURS' EXPOSURE ON THE 100-INCH REFLECTOR.

the Second, pictures the Copernican system The sun—as you see, a very friendly one giving light and heat to man—now furnishes the center for the revolution of the earth and all the other planets; and a simple rotation of the earth itself, once every twenty-four hours on its own axis, is all that is needed to explain the rising and setting of the sun, the moon, the planets and the million other suns called stars.

The Copernican ideas of the solar system are practically those we hold to-day. They have been extended first by the finding of Kepler that the planetary motions are not quite circular, but rather slightly elliptical, with the sun at one focus of the ellipse; secondly, by the gravitational theory of Newton, which accounts for planetary motions with the help of an inverse square law of attraction; and finally by the improved gravitational theory of Einstein, which gives the results of Newton as a close approximation, but then goes on to the treatment of phenomena not included in Newtonian theory. The next illustration, Fig. 6, gives a more modern diagram of the solar system, showing to scale the orbits of the earth and other planets, including the little planet Pluto, discovered in 1930 at the Lowell Observatory in Arizona. The diagram has to leave out the orbits of Mercury and Venus, which are inside that for the earth. It also has to omit the stars, since they are of course far beyond the confines of the solar system; the distance



Mount Wilson Observatory.

FIG. 20. DARK AND ILLUMINATED MATERIAL IN ORION.

THREE HOURS' EXPOSURE ON THE 100-INCH REFLECTOR.

Mount Wilson Observatory

FIG. 21. EXPANDING RING AROUND NOVA AQUILAE,
APPEARING FIRST IN 1918, TAKEN IN 1922, 1926 AND 1931 WITH 100-INCH REFLECTOR.

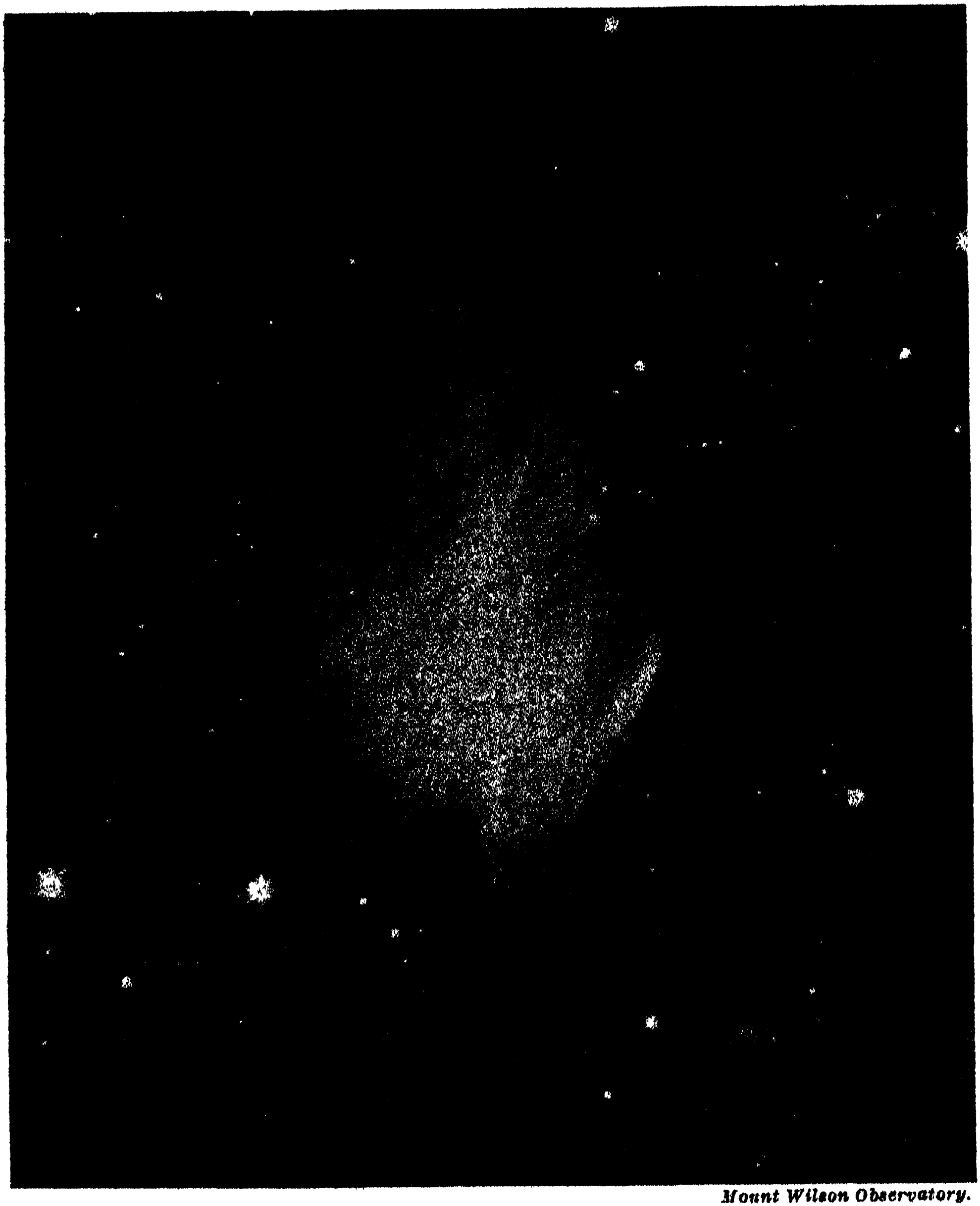
to Proxima, the nearest star we know, is 7,000 times as far as that to the outermost planet, Pluto.

I now wish to show you some actual photographs of astronomical objects in the solar system, that is, in the neighborhood of our own sun, the star around which we ourselves revolve. First of all we have the moon, for us the nearest object of all, and of special interest to astronomers since its distance and rate of revolution around the earth furnished Newton with the needed quantitative test for his theory of gravitation. Fig 7 gives a portion of the moon's surface near enough so that you can see its mountains, plains and characteristic craters. Next, Fig. 8 and Fig. 9, we have two photographs of the sun, showing sunspots, faculae, flocculi and giant bursts of vapor from the surface. By making use of the spectroheliograph invented by Dr. Hale, these photographs were taken, the first with the light emitted from calcium atoms in the sun's surface, and the second with the light from hydrogen atoms. And now, Figs. 10, 11 and 12, three of the planets: Mars, with its surface markings and polar cap of snow, two views, one time partially and one time completely illuminated by the light of the sun; drawings of Jupiter, with its belts and four of its eight moons; and two views of Saturn with its rings, both taken on the same night. Finally, as another kind of member of the solar system, Fig. 13, Halley's Comet, one of those conglomerations of particles, dust and gas which periodically sweep in close around the sun in their long and narrow elliptical orbits.

THE STELLAR SYSTEM

So much for typical objects in the neighborhood of the sun. But the sun is only one star out of many, big and bright for us because of nearness, but far surpassed in absolute size and luminosity by numerous others. Hence for the next stage of cosmology we must turn to the study of the milky way or galaxy, of which our sun is only one unimportant member.

As I prefaced the earlier stages of cosmological study with maps of the "flat" earth and with diagrams of the Ptolemaic and of the Copernican systems, so I can now preface the present stage by a diagram of the whole galaxy, Fig. 14. This diagram was made under the direction of Dr. J. S. Plaskett, director of the Dominion Astrophysical Observatory at Victoria, for his Halley lecture on "The Dimensions and Structure of the Galaxy." It shows the galaxy as we think it might appear when seen edge-on from the outside. At right angles to the present view we should expect to see a great spiral structure with a bright central nucleus, as we actually



Mount Wilson Observatory.

FIG. 22. ANOTHER PHOTOGRAPH OF ILLUMINATED MATERIAL IN OUR OWN GALAXY.

shall see later on, in photographs of spiral nebulae or other galaxies that lie outside our own.

Just as it is hard "to see the forest because of the trees," so it is very difficult to study the structure of our own galaxy from a place inside it. Nevertheless, there is nothing in this diagram in serious contradiction with our present knowledge. The dark line down the center represents—with perhaps too regular an outline—a layer of absorbing dust for which we shall later see evidence. And it is dust such as this which presumably prevents us from seeing the bright central nucleus of our own galaxy. The location of the sun, with the earth and other planets, is indicated by a label well to the left of the center of the galaxy. The smaller dots, outside the sharper limits of the galaxy, represent individual stars with a gradually decreasing density of distribution as we get further and further away; and the larger dots represent globular clusters of stars which were first used at Mount Wilson by Shapley in studying the shape and size of the galaxy.

The diameter of the galaxy is of course enormous, but may now be set with some accuracy at about 30,000 parsecs or 100,000 light years. To give an idea of what this figure means, it will be remembered that light travels 186,000 miles a second. It takes eight minutes for light to travel from the sun to the earth, one hour and 20 minutes from the sun to Saturn, the furthest planet known to the ancients, five hours and 30 minutes to Pluto, the most distant planet now known, 4.3 years from the sun to the nearest star Proxima, 8.8 years from the sun to the brightest star Sirius, but 100,000 years to travel the length of the galaxy.

I next wish to show you some actual photographs of objects inside the galaxy. First and most important of all come of course the stars themselves, numbering, according to the estimate of Seares, of Mount Wilson, somewhere around thirty thousand million for the galaxy as a whole. Unfortunately the stars do not give imposing pictures, since no star is near enough and big enough to produce more than an unresolved point of light, even with the most powerful telescope. Perhaps the best I can do is to show (Fig. 15) two photographs, made five years apart by Barnard at the Yerkes Observatory, of the triple star Krüger 60, showing in the five years a small rotation of the closest pair around their common center of gravity. The size of image in such a picture is determined by the brightness of the star itself through the effect of "photographic spreading."

Photographs of groups of stars are much more interesting. Fig. 16 gives two different exposures of a so-called open cluster of stars (Messier 35); in Fig. 17 we have some great clouds of stars in the constellation Sagittarius; and in Fig. 18 a globular cluster of stars (Messier 3), the kind of object already mentioned as used in outlining the galaxy.

In addition to the stars themselves we can also find great masses of gas and dust in the galaxy, and when these are totally or partially illuminated by a nearby star the result can be very striking. Figs. 19, 20, 21 and 22 give four quite different examples of such illuminated stuff, Fig. 21 showing the appearance in 1922, 1926 and 1931 of the expanding ring of material shot off by the explosion of Nova Aquilae in 1918.

(*To be concluded in the January issue*)

THE RELATION OF ORGANISMS TO THE SALTS OF THE OCEAN

By Dr. LAURENCE IRVING
PROFESSOR OF EXPERIMENTAL BIOLOGY, UNIVERSITY OF TORONTO

MAN and other animals congregate along the borders of the sea, where they can find their prey in the life which is so abundant there. Along the shores the conditions for life seem to be well fulfilled, for tides and waves, varying with the time and weather, present in the constantly changing environment an opportunity for each organism to choose its favorable conditions. It is this area of transition from land to sea that typifies the sea for most of us and which gives us the idea that to change is the most striking characteristic of the sea.

But these changes in the sea are largely superficial and littoral, and their impressiveness depends mainly upon the point of view or upon the personal motives of the observer. The occasional voyager is inclined to view with concern the disturbance which is effected by the superficial movements of the sea upon sensations which are adjusted to his usual firm base on solid land. But for the practiced mariner, the only uncertainty about the sea rests in the accuracy of his own calculations.

The sea is the regulator of temperature and humidity along the coasts, where climate is always moderated by the tempering effects of nearby large masses of water, and for animals that live in the sea, environmental conditions are relatively constant. Imagine the simplicity of existence for a mammal like the seal, in spite of the fact that as a mammal it still exists relatively as an alien in the marine environment. There are no diurnal changes of temperature. Even the seasonal changes are small, and practically they are evaded by simple and sensible migratory habits. The effect of gravity is unimportant for an animal living in a medium which has the same specific gravity as its own body. No hills nor valleys interfere with locomotion, and movement in three dimensions is easier than it is for us in two. In fact, considering the comfortable appearance of the seal, it would seem that part of its expression of satisfaction is derived from the realization that its ancestors wisely recognized their error in competing for a variable terrestrial habitat and reverted to the relatively uncontested and practically uniform environmental conditions which prevail in the

Although the sea is more uniform than the land in certain physical characteristics, it is even less variable in its chemical properties. The sea is a saline solution, which contains on the average about 3.4 grams of salt in each 100 cubic centimeters of water. Certain circumscribed areas, like the Baltic, may be diluted by the fresh water which runs in; or other areas, like the Red Sea, may be concentrated by the hot dry climate to which they are exposed. But the greatest part of the sea is uniform in concentration.

The salt which is contained in sea water is not common salt, or sodium chloride, alone, as can be recognized from the bitter taste of sea water. In addition to sodium chloride, which forms 85 per cent. of the salt, the sea contains at least traces of about half of the elements. Seven of these constituents make up 99.8 per cent. of the dissolved material, as is shown in Table 1, and these are always present in the same proportions in all parts of the sea. The dilution which occurs near large watersheds or the slight concentration in the dry tropics scarcely alters the composition of the marine salts so that the result is detectible. This fact was put forward as the result of the careful and judicious

TABLE 1

THE COMPOSITION OF SALTS OF THE OCEAN*

	Per cent. of total dissolved matter
Cl	55 3
Na	30 6
So_4	7.7
Mg	3.7
Ca	1 2
K	1 1
Co_3	0 2
Total	99 8

* Tabulated by Clarke (1924) from Dittmar's analyses.

analyses made by Dittmar[1] on samples collected during the famous expedition of H.M.S. *Challenger*. These results summarize one of the finest series of analyses which have ever been performed, and their significance is a tribute to the judicious choice of methods on the part of the analyst and to the scrupulous care with which the analyses were executed and described. Subsequent analyses have only confirmed the results and conclusions of Dittmar.

The composition of marine salts is uniform throughout the entire volume of the ocean. The ocean can then be regarded as a single salt solution of known composition. The volume of this solution entitles it to special consideration because it is probably the largest homogeneous mass of material in the universe which can be defined in terms of a number of common and familiar components. Any generalization which can be made upon a mass of such size is also biologically significant, because the ocean constitutes a well-populated environment of organic life.

Marine animals and plants are quite sensitive to the salt composition of the water in which they live. This sensitivity is observed in the effects which salts of calcium and potassium exert upon the heart beat, the excitation of muscle and nerve, permeability and penetration of cellular and tissue membranes and visible changes in protoplasmic structures. And definitely related to this sensitivity is the discrimination which marine organisms exercise in selecting from among the marine salts only certain ones of the constituents which they incorporate in their protoplasm. It is this relation between the mineral composition of marine organisms and the ocean salts which we wish to consider more carefully.

A favorite method of approach to the description of the environmental conditions which now exist is to search through their history toward their origins. The composition of the sea is now uniform throughout its spatial dimensions. Although the change is not rapid, the sea has nevertheless gradually become a more concentrated solution of salts during the time which has left geological records. The simplest view of the origin of the sea is that it was originally a body of water which was either nearly fresh or at least much less salty than it is to-day. Slow erosion of the rocks dissolved them and eventually transported the soluble salts to the sea, where evaporation of water left behind the salts in a solution which steadily became more concentrated. The original surface of the earth was covered with igneous rocks, and it was from the eroded products of these igneous rocks that the marine salts were ultimately derived.

As an initial step in our search for the origin of the marine salts, we can compare (Table 2) the relative abundance of the components of the marine salts and of the igneous rocks. The comparison is not very good, for the substances which make up 99.8 per cent. of the ocean

TABLE 2

AVERAGE COMPOSITION OF IGNEOUS ROCKS AND OF THE OCEAN SALTS*

	Igneous rocks Per cent.	Ocean salts Per cent.
Cl	0 06	55.3
Na	2 50	30.6
SO_4	0.10	7.7
Mg	2.29	3.7
Ca	3.47	1.2
K	2 47	1.1
Total	10.89	99.6

* From Clarke, 1924, p. 29.

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[1] W. Dittmar, "Report on the Voyage of H.M.S. *Challenger* 1873–76.—"Physics and Chemistry," Vol. 1, 1884.

salts only amount to 10.89 per cent. of the igneous rocks. A further objection to the view that igneous rocks are the source of marine salts is the fact that these constituents are quite different in the relative abundance in which they occur; for in the ocean salts the substances are in order of decreasing proportion

$$Cl > Na > SO_4 > Mg > Ca > K.$$

while in the igneous rocks, the order is partly reversed, and

$$Ca > Na = K > Mg > SO_4 > Cl.$$

After all, it is apparent that much of the eroded material derived from igneous rocks was simply disintegrated and transported by streams to nearby valleys, with the result that only a fraction of the components of the igneous rocks was ever dissolved and transported for any great distance toward the sea. But among the elements which are common to the igneous rocks and the sea there has been a process of selection which has acted to preserve in solution chloride and concentrate sodium, while potassium and calcium have been lost. This view is made more reasonable by the fact that calcium and potassium are more abundant in the sedimentary rocks than chlorides and sodium, the latter two being in fact rather rarely deposited.[2]

It is a reasonable view to suggest that the marine salts were derived from the igneous rocks, but such a wide gap in time has intervened, and the sedimentary rocks which were removed are so dispersed and various that there is no profit in going beyond this suggestion of the remote relation which exists. A closer precursor of the marine salts can be seen in the dissolved material which the rivers bring to the sea. There is a good example of the recent formation of a salt lake in the Salton Sea, which was made in 1906 when the Colorado River overflowed into the Imperial Valley. But it is not a good analogy for the development of salinity in the ocean, for the salt was derived from saline material in the soil rather than by concentration of the salt in the river water. The other saline lakes are equally poor models, for they have usually been found in the basins of still older lakes which had become saline and deposited their salt as they dried up. The present salt lakes are for the most part only the re-solution of these earlier deposits.

The ocean is unique as a body of salt water. But it is easy to infer the development of its salinity from the course of present events. The rivers annually bring to the sea a large amount of dissolved material. As the water of the sea evaporates it leaves behind the salt, and this process of chemical denudation and concentration must have occurred for as long a time as water has been condensed upon the land and evaporated from the sea. The processes of chemical denudation have long been appreciated and carefully examined. The waters of all the rivers have been analyzed and their present annual contributions to the ocean salts have been compiled by F. W. Clarke.[3] These figures are listed in Table 3.

TABLE 3

COMPARISON OF OCEANIC AND FLUVIATILE SALTS

	Annual from rivers (metric tons × 10^3)	In ocean (metric tons × 10^{12})
CO_3 ...	961 350	95 6
SO_4 ...	332 030	3,553 0
Cl	155 350	25,538 0
Na	158,357	14,130 0
K	57 982	510 8
Ca	557 670	552 8
Mg	93.264	1,721 0

When the ocean salts and the fluviatile salts are compared, it is plain that their compositions are quite different. In the ocean salts the components are, in diminishing order of abundance,

$$Cl > Na > SO_4 > Mg > Ca > K > CO_3$$

whereas in the fluviatile salts, the order is

$$CO_3 > Ca > SO_4 > Na > Cl > Mg > K.$$

In some respects the positions are quite reversed, and if we are to regard the fluviatile salts as the source of the ocean salts, then some process of selection must have selectively precipitated calcium and the carbonates from the river salts, while it has precipitated the chlorides and sodium to a much smaller degree.

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[2] F. W. Clarke, U. S. Geol. Survey Bull., 770, 1924.

[3] *Ibid.*, p. 138.

The view that the salts of the ocean originated by concentration of the salts which are brought in by the river waters has been commonly advanced. Proceeding on the basis of that assumption, a simple calculation provides an estimate of the age of the ocean.[4] If the total amount of a substance in the sea be divided by the annual contribution of all the rivers, the quotient will indicate the age of the ocean. This procedure has been frequently followed, choosing by preference the element sodium as an indicator. The net result of the calculation indicates that the ocean is about 90,000,000 years old. A number of corrections for this figure have been carefully reviewed by Clarke.[5] They include an allowance for the fact that the earth's surface, which was originally covered with igneous rocks, is now about three quarters covered by sedimentary rocks, with the probability that in former times the sodium content of the rivers was greater than it is at present. These corrections would still leave the age of the ocean at about 70,000,000 years, which is apparently consistent with the duration of other geological processes.

Suppose we were to attempt an estimate of the age of the ocean on the basis of the time required for the rivers to supply to the sea the other substances beside sodium. This has been done in Table 4, and the results are not at all concordant. It is not our particular problem to estimate the age of the ocean and we will accept the geologists' figure, which is consistent with the steady accumulation of sodium. But the disagreement suggests that the sea has treated each component of river water in different fashion. In several conspicuous instances the differential treatment appears to be the result of organic activity, and we are selecting these cases in order to demonstrate the significant relation of organisms to the mineral composition of the sea.

TABLE 4

CALCULATIONS OF AGE OF OCEAN (WITHOUT CORRECTIONS)

$$\begin{array}{lcccc}
 & \dfrac{\times 10^{12}}{961\,350 \times 10^{8}} & & \dfrac{95 \times 10^{13}}{96 \times 10^{7}} & 10^{5} \\
\text{Ca} & \dfrac{553 \times 10^{12}}{557\,670 \times 10^{8}} & & \dfrac{55 \times 10^{13}}{56 \times 10^{7}} & 10^{6} \\
\text{K} & \dfrac{510 \times 10^{12}}{57982 \times 10^{8}} & = & \dfrac{51 \times 10^{13}}{58 \times 10^{6}} & = .88 \times 10^{7} \\
\text{SO}_4 & \dfrac{3553 \times 10^{12}}{332\,030 \times 10^{8}} & & \dfrac{36 \times 10^{14}}{33 \times 10^{7}} & = 10^{7} \\
\text{Mg} & \dfrac{1721 \times 10^{12}}{93264 \times 10^{8}} & = & \dfrac{17 \times 10^{14}}{93 \times 10^{6}} & = 18 \times 10^{8} \\
\text{Na} & \dfrac{14\,130 \times 10^{12}}{158\,357 \times 10^{8}} & = & \dfrac{14 \times 10^{15}}{16 \times 10^{7}} & = .8 \times 9 \times 10^{8} \\
\text{Cl} & \dfrac{25\,538 \times 10^{12}}{155\,350 \times 10^{8}} & = & \dfrac{26 \times 10^{15}}{16 \times 10^{7}} & = 1\,6 \times 10^{8}
\end{array}$$

Let us regard the results in the order of those which give the largest quotient and so suggest the greatest age of the ocean. On the basis of chlorine, the quotient is too great, and it is suggested that some chloride was originally present in the waters of the sea.[6] It is not likely that considerable quantities of either sodium or chlorides have been precipitated, for they do not occur in more than traces in most of the sedimentary deposits. Since no considerable deposits of chloride have been discovered the inconsistency in regard to chlorine can not be attributed to selective precipitation.

The quotient for magnesium suggests an age of less than 20 million years. If magnesium had been precipitated more rapidly than sodium, the result would be explained. Sedimentary deposits containing magnesium salts are well known. Many organisms fix small quantities of magnesium in their shells or skeletons, and the corallines contain magnesium next in abundance to calcium. It is certain that a considerable quantity of magnesium has been precipitated by organisms, but it is difficult to account for the dolomites and other magnesium deposits on the basis of organic activity alone. The fact but not the extent of magnesium precipitation by organisms is evident.

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[4] *Ibid.*, p. 150.

[5] *Ibid.*, p. 154.

[6] *Ibid.*, p. 142.

The result of the calculation on the basis of sulfate comes next in order. Following the implication that a small quotient signifies more rapid precipitation, there should be evidence in the sulfur-containing deposits. It is not available in quantitative terms, but deposits of sulfur, sulfates and sulfides of non-igneous origin are quite common. Sulfur is an element which is easily oxidized or reduced and which forms many compounds. It is an element upon which the sulfur bacteria depend and which they precipitate actively as sulfur. In fact, it is extensively utilized by all organisms as sulfides. The organic traffic in sulfur is so impressive and it proceeds so frequently toward the formation of reduced sulfur from the soluble, oxidized form that we can easily believe that the metabolic reduction of sulfates has fixed large quantities. Such a process of organic precipitation may well have prevented sulfates from accumulating in the sea as rapidly as the rivers brought them in.

In the case of potassium the sediments contain notably larger proportions than sodium,[7] and the precipitated potassium is located in these deposits. Whether the amounts are of the right magnitude to strike a balance is a question. But it is conspicuous that organisms contain more potassium than sodium. Offhand it would seem as if sodium chloride were the principal mineral component of the animal for the simple reason that we are accustomed to add pure sodium chloride to our food. But the sodium chloride is ingested and promptly excreted, apparently filling its rôle in the rapidity and ease with which it is transported through the body. No appreciable amount appears to be fixed, and it is doubtful whether any of it even enters in any permanent sense into the composition of the cell.[8] Potassium, on the other hand, is more essentially a true cellular component, and it is quite possible that its more intimate incorporation into cellular substances had contributed to its removal from the river salts as they have become concentrated in the ocean.

Calcium and carbonate are the principal components of fluviatile salts, but they are minor components of the ocean. Their removal must have been proceeding at the most rapid rate of all the substances considered. It is also possible to see the precipitated calcium carbonate in the extensive sedimentary deposits. As their fossil structure shows, these are nearly all of obvious organic origin. And at the present time the process of calcium carbonate precipitation proceeds conspicuously in the rapid formation of shells and skeletons.

It might be objected that it is unwarranted to suppose that the conditions seen in the rivers and ocean to-day represent a fair sample of the preceding 100,000,000 years. It is a desperate attempt to extrapolate from a few current years back to a position which is relatively so remote on the curve as is the supposed origin of the ocean. But it is not outright extrapolation of a long curve from a point. For there is no reason for believing in the occurrence of major natural cataclysms, and it would be assuming a cataclysmic change to say that the proportions of sodium chloride and calcium carbonate in the ocean originated directly from the rivers. But that argument has not much positive bearing upon the necessary course of evolution of the oceanic salts. It is certainly impressive, however, that the substances which would need to be abstracted from the fluviatile salts in the course of their conversion into marine salts can be seen in the sedimentary deposits in abundance corresponding to the precipitation which the hypothesis would require. It is also important to consider that organic processes of fixation select the components according to the extent of their precipitation.

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[7] *Ibid.*, p. 140.

[8] L. Irving and J. F. Mauery, *Biol. Rev.*, 11: 287, 1936.

The organic processes which remove minerals are selective. They do not take elements according to their abundance in the environment but according to some peculiar criterion of the organism itself. It may be that the criterion for the selection of a substance depends upon its chemical properties, and the discrimination which is shown toward magnesium and calcium seem to offer good example. Calcium carbonate is only sparingly soluble in sea water, and the sea is probably nearly saturated with calcium carbonate.[9,10] If carbon dioxide is removed by photosynthesis, calcium carbonate is precipitated, a process which rapidly forms visible encrustations upon filaments of certain algae. Magnesium is an element which is similar to calcium in many respects, but it can not be precipitated by the photosynthetic removal of carbon dioxide, nor by any conditions which are naturally attained in sea water.[11,12,13] From these considerations one might say that chemical properties have determined the favor which organisms show in selecting calcium carbonate in the formation of shells, and the fact that magnesium is only a rare component of shells and skeletons.

The distinction is, although interesting, not particularly useful in showing how organisms make their selection. For naturally they can only accomplish chemical reactions which are possible, and if the conditions necessary for the formation of a precipitate are inconsistent with the life of the protoplasm, then the precipitate will not be formed. The significant part of the precipitation exists in the operation which locally affects the solubility of that substance so that it will be precipitated. And in order to secure the conditions for precipitation the organism must modify its environment. Animals and plants can and do precipitate calcium carbonate very rapidly, but in doing so they must work to modify the sea water locally so that the substance becomes insoluble.

Such a reaction as the precipitation of calcium carbonate is reversible, and one might expect that in the sea or in tissues the precipitates would be dissolved again as readily as they were first formed. The precipitation is not, however, reversible in practice; for the first step in precipitation is for the precipitating substances to make contact with each other, and they are highly mobile while they are in solution. Once the precipitation has occurred, the mobility of the substance decreases, and the aggregation of precipitated particles further reduces the probability of contact with the dissolving agent. It is in this way that precipitates which are formed locally by organic activity will not quickly become dissolved again, even though they are in contact with an unsaturated solution. The reversal of precipitation by resolution is qualified by such differences in velocity of the two processes that the reaction proceeds more rapidly toward precipitation.

It has been suggested that the reasons for the selection by organisms of certain mineral constituents and the exclusion of others may be referred to the differences in their chemical properties. The precipitation of $CaCO_3$ is easily accomplished, but magnesium carbonate is soluble under conditions which organisms can produce. Another example is

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[9] J. Johnston and E. D. Williamson, *Jour. Geol.*, 24: 729, 1916.

[10] H. Wattenberg, *Annalen d. Hydrographie u. maritimen Meteorologie*, 59: 273, 1931.

[11] A. R. Haas, *Jour. Biol. Chem.*, 26: 515, 1916.

[12] W. R. G. Atkins, *Jour. Marine Biol. Ass'n. United Kingdom*, 12: 717, 1922.

[13] L. Irving, *Jour. Marine Biol. Ass'n. United Kingdom*, 1926.

seen in sodium chloride, which forms no natural organic compounds; nor does it enter into the processes of intermediary metabolism. It occurs in organisms in simple solution as a soluble salt, and no organic reaction renders it insoluble. But the statement of these differences according to chemical properties is simply another qualitative statement of the facts and does not particularly indicate how living organisms operate upon their lifeless environment.

The most interesting relation appears in the fact that organisms select substances from their environment in an active manner. Either they move about and on more or less random encounters pick and choose what they will admit: or else admitting all dissolved constituents, they excrete some and retain the others. This selection from the environment is one of the principal activities of organisms, and toward its execution they devote practically all their energy. Animals and plants dispose of a very considerable amount of energy, and a large part of it is applied toward modification of the chemical composition of the environment according to their own inherent organic plan. This plan is remarkably uniform, for the different forms of animals and plants display a surprisingly conservative and uniform pattern of chemical activity. The result is that all organisms are applying a large part of their energy to the selection and fixation of a few elements which fit the chemical pattern of their substance.

Just how great is the amount of energy which organisms expend in modifying the chemical composition of their environment? The answer is not numerical but relative, for in the sea, organic reactions are the only ones which can produce appreciable changes in chemical composition. The changes in temperature which occur in the sea are of insignificant influence in altering chemical composition. Currents and movement of water may aid in mixing or separating components, but their influence is not directly visible. The light of the sun is only appreciably effective when applied through the means of photosynthesis. In fact, one may believe that no significant exothermic chemical reactions would occur in the sea without the intervention of organisms. Through them, however, solar energy is constantly applied to the selective precipitation of some elements, and equally important from the view-point of selection from the environment, to the utilization of others without permanently withdrawing them.

From these observations we could say that organisms have been constantly at work fixing some elements and discarding others. They fix calcium carbonate practically irreversibly: they fix some potassium and sulfur and magnesium, while they pass sodium chloride through their tissues as a transient mineral component which is never fixed. Thus the chemical pattern of organisms supplies the discrimination which would modify the fluviatile salts toward the composition of ocean salts, and organisms constitute the only significant agent for such a change which can dispose of the energy necessary for its accomplishment.

If we were to state the relation between the chemical composition of the sea in terms of cause and effect, we should say that the environment is the product of the organism rather than the reverse. Such a simplification of the case involves an assumption of the validity of the idea of significant causality, and to discuss the subject is to impose too great a burden upon a line of argument which has been developed in order to show that organisms have an inherent discriminating preference for certain elements and that they dispose of the energy necessary to make the selection. In conclusion, I will leave the proposition that only organic processes can have applied the energy which has brought the composition of the sea to its present condition.

THE CONTRIBUTION OF CHOLERA TO PUBLIC HEALTH

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LIKE glaciation, floods and famine, disease makes man active, versatile and inventive by shattering his complacency, rendering him supremely uncomfortable, developing his foresight and forcing him to assume some responsibility for his own destiny. Pestilence destroys equanimity and teaches that procrastination is death, action is life, and knowledge is salvation. Under its influence, men think, defy superstition, ignore tradition, and try the new.

Diseases which do most for public welfare strike suddenly, kill quickly, destroy commerce, and cause panics. This fact is clearly seen by comparison. Tuberculosis has contributed a great deal to preventive medicine, hospitalization and public health, but its lack of impact, spectacle and catastrophic effects permits an emotional tolerance where 100,000 deaths from it cause less national excitement than one man trapped in a cave.

Not so with leprosy, yellow fever, virulent smallpox, bubonic plague and cholera—they command respect, insist upon action, and get results. With industry demoralized, business paralyzed, and the death-roll increasing from day to day, the anti-vaccinationist goes to the doctor or to the cemetery, the obstructionist is cast aside, and a thoroughly aroused public demands effective measures of control, makes appropriations to support them, and enacts laws to give them police power.

Leprosy stimulated and developed ancient preventive medicine; bubonic plague was the great activator of medieval hygiene. The former gave rise to isolation; the latter, to quarantine. What these scourges were to the Ancients and to the Middle Ages in the development of public health, cholera is to the modern sanitation of cities and industrial centers in the nineteenth century.

Cholera has been peculiarly persuasive, persistent and successful in its promotion of sanitation. If the public health work it stimulated became highly efficient and by prevention of disease destroyed the obvious reasons for its own continuance and people became indifferent and permitted it to cease for want of support, cholera had pandemics follow pandemics until the dullest nation was unable to forget the disasters it had suffered. Civilization is forever its debtor.

CHOLERA BEGINS ITS WORLD-WIDE MISSION

Just when the comma bacillus first became parasitic for man, like the origin of life on the earth, is still a biological mystery. The disease known as cholera was described by the Ancient Chinese and Hindus. Hippocrates, the father of medicine and the famous physician of the Periclean age, gives considerable details concerning the history and symptoms of the disease. Aretoeus and Celsus were both familiar with it. Cholera has existed in India for many centuries in about the same form as at present. It appeared in the Portuguese settlement of Goa as early as 1543 and in the French district of Pondicherry in 1768.

Armies have ever been the servant of pestilence. European invasions of India, England's opening up of Hindustan to the commerce of Western Asia and

Europe, and India's fostering of trade with the Dutch Indies spread the disease. Cholera held to the routes of armies engaged in war, followed caravans and crossed the sea to nearby islands. Fairs, religious festivals and pilgrimages repeatedly brought crowds together, introduced the disease, and started pandemics which had repercussions even in remote countries.

Of ten such pandemics since 1817, six went by land through Afghanistan or Persia and thence through the Caucasus and Transcaspia to Russia and Western Europe; four took the route via the Red Sea and Egypt and reached the Mediterranean basin by land and by sea. In 1832, cholera embarked from Ireland for Canada and on the eighth of June appeared in a boarding house for immigrants in Quebec. Thirty-six hours later by boat the disease had reached Montreal, 200 miles distant.

Forwarding of immigrants quickly brought the disease to Kingston, Toronto and Niagara. It reached Detroit by similar means and proceeded west along the Great Lakes. At Fort Dearborn, out of one thousand men, over two hundred cases were admitted to the hospital in a week. In September, it was attacking the military posts on the Upper Mississippi. In the meantime, an immigrant ship had started a new conflagration at New York which extended up the Hudson and to Philadelphia and thence westward. In 1833, cholera entered the Gulf ports from Cuba, traveled up the Mississippi and Ohio Rivers and into the interior. It spread over the whole country during 1835–36 and then subsided for nearly ten years.

In 1846, the disease was again on the move. It crossed the Atlantic and started epidemics in both New York and New Orleans. In the two succeeding years it spread from the Atlantic to the Pacific and from Canada to the Gulf. It overtook the "forty-niners" in their covered wagons on the western plains and pursued the gold seekers bound for California via the Isthmus of Darien. Business was interrupted, opening up of the West delayed, and the development of the country retarded.

The fourth pandemic of cholera is said to have originated in the festival of Hardwar in 1865 and to have subsided in the Mississippi Valley in 1873. It seems to have reached the United States from Bombay via Mecca, Marseilles and Havre. On October 12 the *Atalanta* arrived in New York from Havre after having had 102 cases and 23 deaths in passage. Cholera spread along the great intra-national highways of trade and travel and caused a deplorable mortality, especially in the Mississippi Valley. No organized effort was made to prevent the importation of the disease and little done to prevent its extension.

But this pandemic gave a demonstration the public was not likely to forget. It taught with terrible emphasis the necessity of sanitation, the danger of procrastination and the cost of indifference. Cholera has reached our seaboards a number of times since but has been promptly refused admission; if it has slipped through a port of entry, it has immediately been brought under control and eradicated.

IMPRESSIVE HEALTH EDUCATION

As a teacher of sanitation and public health, the vibrio of cholera is effective beyond the reach of skill. It is dramatic in its demonstrations, and is deadly practical. So well did its instruction carry over into life that even a rumor of its approach caused houses to be cleansed, streets washed, marts of trade to become panicky, and citizens to flee their homes.

Its technique and methods have been described by Heinrich Heine with the gift of a literary genius. A masked ball is on in Paris, the dance is in full swing, brave men and fair ladies move to the rhythm of music, and joy is unconfined.

Suddenly the gayest of the harlequins collapses, cold in limbs, and under the mask "violet blue" in the face. Laughter dies out, dancing ceases, and in a short while carriage loads of people are being hurried from the redoubt to the Hotel Dieu to die. To prevent a panic among the patients, the dead are thrust into rude graves in their dominoes. Soon public halls are filled with corpses sewed in sacks for want of coffins. Long lines of hearses stand outside of Pére Lachaise. The rich gather up their belongings and flee the town. Over 120,000 passports are issued at the Hotel de Ville. A guillotine ambulante is stalking abroad, and its effects duplicate the scenes of the Revolution or the plague of Milan.

John B. Rauch, secretary of the Illinois State Board of Health, in his masterly address at the opening of the National Conference of State Boards of Health at St. Louis in October, 1884, in urging the provision of facilities to combat cholera in the United States no less clearly indicated its terrible effects when he pointed out that "This means more than the good to be found in the saving of human life and in avoiding the suffering and misery, the ruined homes, and desolated families which an epidemic always leaves in its track. It means the prevention of panics; it means the prevention of the loss of trade and commerce; it means the prevention of the loss of millions of dollars, all of which would inevitably result from an epidemic of Asiatic cholera in this country. Already the disease has cost southern Europe not less than one hundred million dollars—six million dollars up to October first in trying to prevent its spread in Italy alone—with a loss of four million dollars even in the month of August before the disease had effected a serious foothold; and now it is announced that the decrease of the national revenues of France has been materially aggravated by the reduction from the receipts from railways caused by the cessation of travel consequent upon the prevalence of the cholera epidemic. And yet Europe is only upon the threshold of this epidemic.

"Let us push sanitation by every means in our power, and to the fullest extent . . . in the knowledge that every sanitary reform tells permanently and continuously on the whole body of preventable diseases; and to the extent of such reforms are the conditions made more favorable for the prevention of all epidemics. No comparison is possible between the cost of suppression and the cost of an epidemic. . . . Who shall place a dollar-and-cents value on the lives which would be sacrificed, and the suffering entailed by an epidemic of Asiatic cholera? Shall we wait until the pestilence has landed and obtained a foothold? A single outbreak, possibly a single case, in New York, Chicago, St. Louis, or New Orleans would cost the country millions of dollars." (Shrinkage in the provision market).

Cholera has not been an unmitigated evil. It compelled men to think, to learn and to act. Out of their terrible experience came better living conditions, broader sympathies, greater tolerance and a sense of social responsibility which had tremendous possibilities for the future. Men took inventories of themselves and their communities, caught a vision of opportunities for progress, and moved forward.

Even an unsentimental mandarin, when urged by Russian authorities to adopt preventive measures against cholera, showed that he apprehended its potentialities for good when he replied that "the deaths would allow more room in the world for those who survived, and besides, that cholera chose its victims from the filthy and the intemperate and that no person of courage, who lived with moderation and cleanliness would die of it." Obviously, he lived before the era of bacteriology and was a near-sighted observer.

"A Former Surgeon-General in the

Service of the Honorable East India Company'' as early as 1866 understood that ''epidemic cholera, like the plague and yellow fever, is a main branch of the Universal Sanitary Commission of Almighty God—armed with Herculean power to turn a river of death through the Augean stables of the world's filth and lewdness and drunkenness and ignorance and waste; and in the name of the King of Terrors to compel from purple and fine linen and sumptuous fare a trembling recognition of their mortal brotherhood with nakedness and starvation and pitiful squalor.'' In beautiful language he anticipated the modern discovery that bacteria are great social climbers.

When cholera appears, the enlightened world demands action. The voices of ignorance, tradition and procrastination are lost in the loud insistence that science be used to prevent a catastrophe. Through international conferences, maritime regulations and quarantine have been instituted and detention hospitals provided By the use of visés the routes of pilgrims are now being determined and their vaccination against smallpox and cholera are required. Sanitation has been improved on land and sea. Suffering has given rise to knowledge and progress has been wrung from disaster.

Although cholera is still a major menace in certain parts of the world, it is not likely to be seen again as a pandemic originating in Hardwar or Mecca and spending itself in the Mississippi Valley. When a million pilgrims can camp around Allahabad in 1930 without the occurrence of a single case of cholera, contributions of this disease to sanitation have become invaluable. With proper precautions the Faithful can visit their shrines in safety and business may proceed as usual.

PERSONAL HYGIENE

In a disease as sudden in its onset and as devastating in its effects as cholera, it is not surprising that speculations concerning its nature should be numerous and procedures for its control should be varied. They cover almost the entire field of personal hygiene and are potent factors in the general promotion of health.

Nearly twenty years before the discovery of the vibrio of cholera, Montgomery of Madras warned against ''the vicissitudes of climate''—sudden chilling of air and tropical suns—dry months and rainy seasons. He attached importance to physical fatigue and nervous depression as predisposing causes and was convinced that both were markedly effective in individuals proceeding on long journeys or in soldiers on the march. His observations were correct, but the greater liability to attack was primarily due to increased opportunities for becoming infected and only secondarily to lowered resistance caused by exhaustion.

Excess in eating, drinking and venery were thought to be conducive to the disease. ''Undue abstinence or deprivation of food or the presence of injurious properties in it'' were to be avoided. The evils of overcrowding were recognized and vitiated air was considered ''fatally morbific.'' Lowered vitality from whatever cause will favor the growth of the vibrio of cholera and also decreases the resistance to other diseases.

''The cholera poison'' was known to affect ''with equal virulence'' bedding and towels so that the soiled linen of a patient could spread the disease over a whole district. ''Foul skins'' and the clothing of the ''great unwashed'' were thought to create an atmosphere in which dirt might quickly be converted into ''a nucleus of cholera poison.'' This view led to the advice that particular attention should be given to personal cleanliness by daily bathing and was most likely an important factor in overcoming the prejudice against bathtubs and in the repealing of the laws against them in many cities and states in this country.

SANITATION

No fact of history is more astounding than man's tolerance for filth—his contentment with dirty milk, his use of water contaminated with excreta and the disposal of refuse and his discharges in a way to spoil the landscape and to pollute his food. For centuries his esthetic sense was hopelessly dull, until cholera turned a stream of death into his sea of foulness. Then he began to think.

He conceived "that cholera discharges, if cast away without previous disinfection, may impart their own infective quality . . . to more innocent filth with which they mingle in drains or cesspools, and wherever else they flow or soak . . . thus poisoning . . . subsoil water. . . . If cholera poison . . . gets access even in small quantity to wells or other sources of drinking water, it will infect, in the most dangerous manner."

This conception, which has meant so much to water purification and sewage disposal, did not become a demonstrated conviction until Dr. John Snow in 1854 informed the vestrymen of St. James that the severe outbreak of cholera in London was caused by water from the Broad Street pump and that it would cease if its handle were removed. This it did. A subsequent survey of the well and its surroundings by York showed it to be contaminated by a cesspool which had received excreta from patients with cholera. The users of the well were drinking dilute sewage.

The classic lesson taught by cholera on the necessity of water purification and scientific sewage treatment in more modern times was given at Hamburg, Germany, in 1892. Both Hamburg and Altona, its virtual suburb, took their water supplies from the Elbe River. As Altona drew its water supply from the river below the outfall sewer of Hamburg, its water supply contained more sewage than did the Hamburg water. There was also another difference. Hamburg used the water untreated; Altona, after slow sand filtration. During August to October Russian emigrants were detained in crowded barracks on the bank of the Elbe while *en route* for America. Their sewage was discharged into the river. In a little over two months Hamburg, with a population of 640,000, had 17,000 cases of cholera, 8,605 deaths, and a death rate of 1,342 per hundred thousand population. Altona with a population of 143,000 had comparatively few cases and only 328 deaths. As many of the residents of Altona worked in Hamburg, it is not surprising that some of them contracted cholera.

Of extraordinary interest was the fact that in a certain portion of the towns the boundary line between them ran down the middle of the street. On one side the inhabitants received water from the supply of Altona; on the other, from that of Hamburg. The contrast was conclusive; the people of Hamburg experienced the epidemic; those of Altona escaped.

Robert Koch, the great German bacteriologist, thoroughly studied this epidemic and succeeded in isolating the spirillum of cholera from the polluted water of the Elbe River. He definitely proved that the disease was water-borne. To these crystal clear demonstrations of cholera, reinforced by equally impressive ones of typhoid fever, we owe a great deal for the development in this country of water purification, sewage treatment and rural sanitation.

When the cholera epidemic at Hamburg proved the effectiveness of slow sand filtration in purifying the water of Altona, it led to the use of similar protection for the Hamburg water supply and incidentally to the discovery of the fact that water purification not only produced a diminution in the death rates from cholera, typhoid fever and other intestinal diseases, but simultaneously caused a reduction in mortality rates from non-intestinal diseases. This was noted by Dr. J. J. Reincke, health officer of Hamburg, and confirmed by Mills, Sedgwick and McNutt in this country. After carefully studying the problem, Hazen came to the conclusion that for every death saved from typhoid fever by the purification of water, there were three or four deaths saved from non-intestinal causes.

Subsequent investigations have raised questions as to the validity of the Mills-Reincke phenomenon and Hazen's theorem. But there is no doubt that a pure water supply diminishes the presence of cholera, diarrhea, dysentery and typhoid fever. It is also clear that the absence of intestinal diseases and their debilitating effects tend to insure the maintenance of individual resistance and thereby help to prevent the occurrence of other diseases like tuberculosis, pneumonia, etc. Thus cholera, aided by typhoid fever, compelled a sanitary triumph in an era of epochal discoveries.

Once it was clearly understood that cholera and typhoid fever were water-borne, sewage had to be disposed so as not to cause disease. As sewers were built to discharge their contents into the nearest body of water, difficulties ensued. If the stream receiving the sewage were small, a nuisance occurred, and litigation arose as to riparian rights and damages for pollution of the water; if untreated, the water supplies became infected, or shellfish contaminated, epidemics resulted, and legal action often followed. Modern sewage treatment is a great contribution of cholera and typhoid fever to public health.

CLEANLINESS AND DISINFECTION

Cholera promoted cleanliness with a vengeance. It led to the adoption of extraordinary measures, which were even beyond the need of the occasion and often caused unnecessary expense. Streets were not only swept, but in many cities they were also washed and disinfected. Many of them were so foul that this vigorous cleansing changed their atmosphere, and facilitated transportation. The experience was novel; the example, overwhelming.

It was a general impression in Europe that although cholera could not be excluded by quarantine, it might be "stamped out" by disinfection. Thorough disinfection was declared to be the best means of protection against the disease. To individuals and communities threatened by cholera, thorough was the superlative.

Sewers were flushed with strong disinfectants, docks were cleaned, and nuisances were abated. Conditions likely to give rise to "mephitic vapors" and "poisonous gases" received special attention. Among outstanding dangers were sewers "which ran up-hill, and water closets, bathtubs, and stationary wash stands acting as ventilators for them." "In London in 1859, 20,000 pounds were expended in flushing the sewers with fresh water; and 110 tons of lime and 12 tons of chloride were thrown in every day at a weekly cost of 1,500 pounds." Some towns were rendered bankrupt by the thoroughness of their disinfection.

Sulphate of iron or copperas was considered the most efficient and potent. Carbolic acid and other coal tar preparations were second choice. Disinfectants were poured into the pipes of wash stands, bathtubs and water closets. Their outlets were closed with cotton at night because "it has been observed that when meat is exposed to air which has been passed through cotton, it will not putrefy for months."

Freshly prepared lime was used to disinfect outdoor privies. Solutions of chloride of lime were poured into sinks, soil pipes and other places from which offensive gases arose. House drains and cesspools were similarly treated. Sulfur was burned, goods fumigated and the premises were whitewashed. Soiled linens were burned, and in Cairo rags were disinfected by boiling for four hours. Cholera's contribution to disinfection is large and important; the extra cleanliness it produced probably saved more lives from other filth diseases than the deaths it caused.

QUARANTINE

Cholera did not inaugurate quarantine but modified, amplified and gave it greater international significance. The use of isolation to control disease is almost as old as history. The ancient Hebrews employed it centuries before the Christian Era, and the sanitary code of the Pentateuch describes rather in detail procedures to make it effective. In 1374 the Venetian Republic excluded infected and suspected ships and made the first quarantine of infected areas in 1403, so-called because travelers from the Levant were isolated in a detention hospital for forty days. With the appearance of cholera, this measure was promptly used to control it.

However, it was found to be much less effective than had been anticipated. As a result, the impression soon became general in Europe that quarantine could not be relied upon to control cholera. It failed because carriers and mild cases were missed and passed into localities to start epidemics. With the discovery of the comma bacillus quarantine was placed on a sound scientific basis, and at present has a definite place in the control of cholera.

Highly fatal pandemics produce a harvest of fruit as well as a crop of tares. Cholera caused much sickness, misery and death. Under its mortal magic, hope of accomplishment gave place to a pervading sense of futility, and the enthusiasm of progress was overwhelmed by an appalling uncertainty. Civilization staggered from the shock of cholera and men wondered if another Dark Ages were at hand when bubonic plague wrecked empires and threatened man with extinction. Fatalism became dominant, moral idealism suffered a sag, and degeneration cast its ominous shadow across many lands of promise.

But cholera has had a brighter side! It gave terrible emphasis to the urgent need of sanitation—the necessity of pure drinking water, the proper treatment of sewage, a safe and adequate food supply, refuse disposal, better housing, cleanliness and an efficient organization to prevent and to control contagion. Its contributions to epidemiology are classics. The Broad Street well and the Hamburg epidemics will continue to teach generations yet to be born how intestinal diseases are spread. This scourge improved methods of disinfection and greatly increased the efficiency of notification of disease.

Cholera played a most significant rôle in the development of public health administration. Under its stimulation, maritime councils were created, quarantines established, immunization made obligatory, and suspected carriers of disease kept under surveillance. It motivated the calling of international conferences on sanitation and caused treaties to be made for the control of pestilence. Under its pressure, national health agencies came into being, legislative bodies assembled and laws were passed to promote health and to prevent disease. Through its influence boards of health were appointed, funds provided for their support, and commissions were set up whose reports mark the beginning of a new era in public welfare.

IN QUEST OF GORILLAS

By Dr. WILLIAM KING GREGORY
CURATOR OF COMPARATIVE ANATOMY AND OF ICHTHYOLOGY, AMERICAN MUSEUM OF NATURAL HISTORY; PROFESSOR OF PALEONTOLOGY, COLUMBIA UNIVERSITY

XIII. GORILLAS, MEN AND SLEEPING SICKNESS

By H. C. RAVEN
ASSOCIATE CURATOR OF COMPARATIVE ANATOMY, AMERICAN MUSEUM OF NATURAL HISTORY
LECTURER IN ZOOLOGY, COLUMBIA UNIVERSITY

On January ninth I stayed in camp and sent men out in several directions to look for gorillas. In each party were two men. In case they should come upon gorillas one man was immediately to return to camp for me, while the other man was to follow the gorillas, making a trail so that he could easily be followed when we arrived. They found no gorillas anywhere, so when they returned late in the afternoon I hunted to the east and south of camp.

On January eleventh I slept out in the forest listening for gorillas. I heard them call twice and saw many places where gorillas had fed a short time before. I returned to camp about 10:30 A.M., where I heard a palaver between Ngom and Ndongo about one of Ngom's wives. Ngom had been grouchy for three or four days; in fact, it seemed to me that nearly every one in camp was grouchy, but I did not know the reason. Finally this morning Ngom told me that Ndongo had taken one of his wives. Ndongo heard this and said: "Him lie. I no bin take dem woman."

"Him lie," Ngom replied. "Me bin talk for dem woman. Woman he agree. Ndongo no agree." He added furiously, "Ndongo he go pay," to which Ndongo replied, "Me no pay."

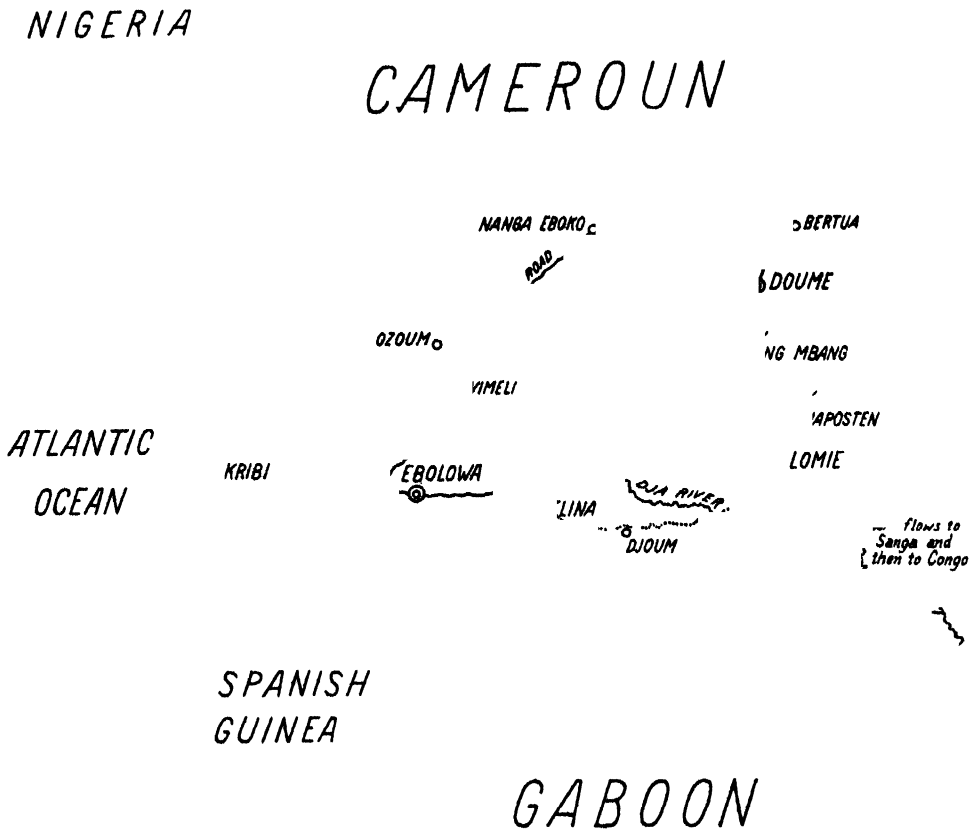
As Ngom was a chief he had a policeman at his orders and he threatened to have Ndongo taken to the French officials at Lomie and put in jail. Ndongo was my wash-boy and I did not want to lose him just then, nor did I want Ngom to take several days off to go to Lomie. I therefore told Ngom to let the matter rest until we returned to Djaposten, where we could talk the palaver, and he agreed to this.

However, there was still bad feeling, and finally the day came to move camp. Ngom sent for more porters, but when they arrived there was one man short and Ngom ordered his wife to carry the extra pack. I was busy packing up and getting the porters under way and at last all the loads were gone. Tsama had prepared a roasted plantain for my luncheon and I waited some little time for it to cool before I could eat it. Thus the others were far ahead when I started with Tsama and a head-man named Olen, who had two dogs he hoped to sell me. Following the trail toward Djaposten for about three miles in the heavy forest, we came upon Ngom standing beside his wife with a whip in his hand. The pack was lying on the ground. The woman was crying, and I could see a large welt across her back and a couple more on her thighs. As we approached, Ngom ordered her to put the pack on her head, but instead she started to cry again. Ngom was in a rage. He jumped at the woman and struck at her, but the switch broke. He took out his knife, cut a piece of liana hanging near by and struck her once with this before I could take it away from him. He said she was making a fuss just because there was a white

FERRY OVER THE NLONG

FLOODED ROAD

THE ROADS IN THE CAMEROUN ARE MADE WITH DEEP DITCHES ON EACH SIDE, AND LEMON GRASS IS PLANTED ALONG THEM, AS ITS MATTED ROOTS PREVENT THE WASHING AWAY OF THE SOIL



MAP OF THE FRENCH CAMEROUN SHOWING THE LOCATION OF SOME OF THE PLACES MENTIONED IN THE TEXT.

man there. I told Tsama and Olen to put the pack on her head and we all moved on.

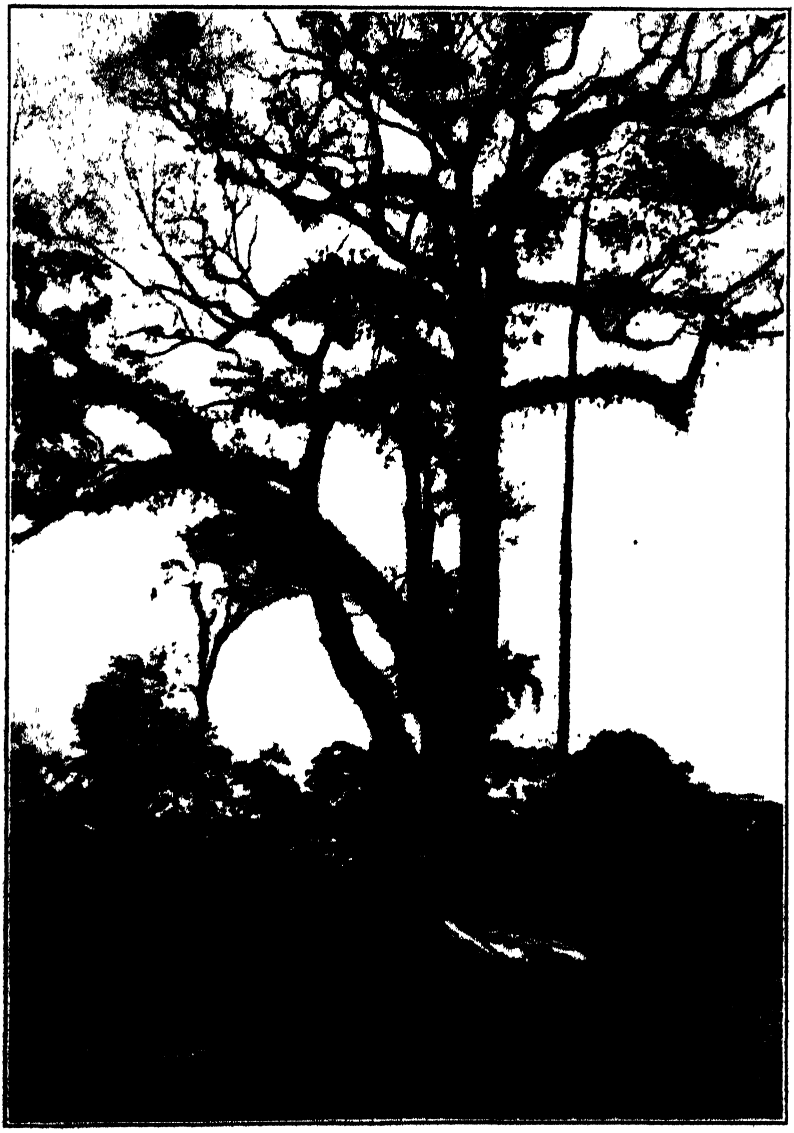
The next day I said to Ndongo: "Ngom he got police, he go take you for Lomie. *Chef-de-Poste* he go say, Ndongo he bad man, den he make you pay hundred franc. Police go make you sleep for ground den flog you plenty. Maybe police make you work for route. Dis palaver look bad plenty; Ndongo he better go pay Ngom just now, today." Ndongo said, "Ya, me go pay."

When Ngom came along I called him and said: "Maybe you go take Ndongo for Lomie. *Chef-de-Poste* go say, Ndongo be bad plenty for take dem woman. You go say, Monsieur *Chef-de-Poste,* you go make Ndongo pay hundred franc for me. Maybe *Chef-de-Poste* he go say, Ndongo take you woman, he pay hundred franc. Maybe Government take dem money, no give it for Ngom." Ngom replied: "Ndongo he bin take my woman, he go pay." I asked, "How much franc Ndongo go pay?" "Fifty franc (the equivalent of two dollars), he answered. Ndongo paid. The palaver was finished.

The following day when Ngom was about to leave for his house after visiting us, I saw him offer Ndongo a cigarette. Ndongo asked him to wait a minute and he would walk down to the village with him. In perfect peace they departed.

The routine of hunting continued

without much variation. We had slept in the forest several nights in order to listen for gorillas. On the night of January eleventh we slept near a little trail about three miles from camp. During the night I heard a gorilla talk only once, far away and to the north, in the direction Ngom said they had been feeding the day before. At 5:30 A.M. we had a severe electric storm with much thunder, lightning, wind and rain. Of course we were all wet through, as we had no shelter, sleeping on the ground, but we were not cold, for we managed to keep a good fire going It was very dark in the forest until 7·00 o'clock. Olen, a chief of one of the villages of Djaposten, with the two dogs which I



DESERTED HUT BESIDE THE ROAD AT BILULU.
SECOND GROWTH FOREST HAS SWALLOWED UP THE REMAINS OF GARDENS.

hoped to use in hunting gorillas and chimpanzees, was with us at this time.

On the thirteenth of January Ngom, Nkoul, Olen and his two dogs and I hunted all day northeast of camp. We trailed a family of gorillas nearly half the day. Once Ngom and I got near enough to hear them when they crossed a palm swamp. The dogs were kept on rattans, so they were useless. We saw fresh elephant tracks, but in all the hunting we had not once had a chance to shoot an adult gorilla.

On the sixteenth of January we returned to Djaposten. The porters had found a rotten antelope which had been killed by a leopard and partly eaten. They took the remainder, but I warned them that I would look over every load when we arrived at Djaposten and if any load smelled of that meat, the porter would not be paid. It amused them very much when I sniffed the loads as they deposited them at Djaposten. I learned later that by agreement one man had carried all the antelope meat, while his load had been divided up among the others.

A CHILD WITH SLEEPING SICKNESS. THIS CONDITION REPRESENTS THE FIRST STAGES OF TRYPANOSOMIASIS.

The day following my return to Djaposten a native brought me a live scaly ant-eater, of which I took some motion pictures. This animal was much more agile than the much larger East Indian pangolin.

On January twenty-first I went with Meyong to a little village about four miles from Djaposten, toward Lomie, to see a man of that village who was said to have killed many gorillas and chimpanzees. This man, Malong, and I hunted together all day toward the northeast, most of the time in second growth. I shot two large plantain-eaters and three monkeys, two with white on either side of the crown and one red-tailed. I also saw some large dark-colored monkeys with a white spot on the nose. On this hunt I found a very fine fungus, in form like a toadstool. The top was a flat disk with concentric growth rings. It was about eight inches in diameter, dark brown in color, with a stem about three eighths of an inch in diameter, also brown; the under side of the disk was cream-colored, not gilled like a mushroom but having a multitude of pores.

Malong was terribly scarred on his left breast, shoulder and arm, and had four deep scars in his back. I asked him how he received the wounds and was surprised to hear him say that they were made by a gorilla four or five years before. He said that at that time he had not attained his full growth, did not have a beard and did not know women.

I questioned him about it two or three times until I got the whole story. He had accompanied a party of rubber-gatherers into the forest. It was their habit not to get up very early in the morning, but he got up at dawn and hunted monkeys with his cross-bow, which shoots a tiny poisoned dart He saw monkeys in second growth trees and was approaching them when suddenly he was confronted by a large male gorilla on the ground. It rushed at him, stopped, looked and then went off a short distance Then it came on again and he turned to run The gorilla grabbed for his buttocks, missed and caught his ankle. He struck the animal on the hand and in the face with the cross-bow and it again retreated a few paces and stood watching him. At this point a female gorilla came down from a near-by tree and the male rushed him again. He struck it in the face with his fist, all the time shouting for his friends to bring a knife, but they did not hear. The gorilla again retreated a few feet, looked at him and again came on, this time grabbing him by both ears and trying to bite his face, but he turned his head down. The gorilla was holding his right hand and tried to bite it, but he managed to jerk it out of his mouth, getting a nasty cut on the back of his wrist from the canine. The animal held him and bit his chest, shoulder and arm, but he finally struck it so that it released him and he escaped.

Except for his left arm, which is weak, he is a powerful man. He says that when he remains inactive the arm gives him very little trouble, but when he uses it much it swells and becomes very painful. Pus frequently forms in the scars and one or two were in this condition at that time. It was almost unbelievable that he was not killed by the animal.

Such experiences are rare, but occasionally gorillas do harm the natives. In the same village was a woman who years before had complained to the men that she was afraid to go into the low second growth to gather plantains and bananas because gorillas were there. The men told her to make a noise and the gorillas would run away. This she said she did, and a big gorilla rushed toward her, and as he went he gave her a back-handed slap that knocked her down and almost tore one breast off.

A BOY WITH SLEEPING SICKNESS.
THIS LETHARGIC AND EMACIATED STATE REPRESENTS A LATER STAGE OF THE DISEASE.

Near the end of my stay in the Cameroun I had carried my embalmed gorillas down to the coast on a motor truck and

DR. W. S. LEHMAN AT WORK IN HIS CLINIC IN THE INTERIOR OF THE CAMEROUN

A SURE WAY TO SEE THAT THE PATIENT GETS THE PROPER DOSE IS TO PAINT THE AMOUNT ON HIS DARK SKIN WITH CHALK.

was returning when I met three natives carrying a man on a sling made of a pole and some burlap bags. As I came near they asked me if I would take the sick man to the next village on the truck. When I asked what was the matter with him, they told me that he had been bitten on the leg by a gorilla over on a near-by hill I asked, "Where is the gorilla?" and they replied, "Oh, he ran away" So I took him along to the village. On the way there the men told me that the sick man had been hunting with dogs for wild pigs when one of the dogs had run close to a gorilla. The animal dashed after the dog, who took refuge between his master's feet, and as the man turned to run the gorilla grabbed him by the ankle and sank his large canines into the calf of his leg. When we reached the village I told them to take off the dirty rags bound around the leg, so that I might see the wound When I looked at it I could clearly see the marks of the gorilla's great canines. I remarked, "This is no fresh wound. When did this happen?" They replied, "About three months ago" With medical care his wounds would probably long since have healed.

One of the medical missionaries told me of a case where a gorilla had been shot and wounded by a native hunter. The animal charged the man and bit him on the arm or leg and then ran off. The doctor was called to attend this man's wounds. In addition to the bites the doctor saw a clean, deep cut through the man's knee. He said, "This wound was made by a knife, not by a gorilla." The wounded man maintained that it was made by the gorilla, but later his companion admitted that when the gorilla grabbed his friend he struck at it with his big machete-like knife. The blow missed the gorilla and cut his friend's knee.

As the natives travel through the forest, if they hear gorillas near by they make a detour to keep out of their way. On the other hand, should a group of natives, talking as they walk along, come near a group of gorillas, the gorillas would quietly move off and, unless followed, would make no demonstration. It is only when they are followed or come upon suddenly, when some of the group are feeding on fruit or up in a tree, that an old male will attack.

For centuries past the gorillas and natives have been competitors. As the native population increased, new villages would be formed and more clearings made. Then epidemics would occur, killing off great numbers of natives, and their gardens would be neglected to run into second growth. The gorillas, with a constitution so nearly like that of man that they can find more food in human plantations than in the virgin forest, would move into these deserted clearings. There with an abundance of food they throve and congregated, to such an ex-

AN OLD WOMAN WITH SLEEPING SICKNESS.

tent eventually that if only a few natives remained they were actually driven out because of their inability to protect their crops against the gorillas. But with the advent of the white men's government, with the distribution of firearms among the natives, preventive medicine and the treatment for epidemic and infective diseases, man has the upper hand at present in this age-long struggle.

Natives often told me· "If we could only find a group of gorillas up in a tree after fruit, we would be able to kill all or any we wished " On one occasion while I was at Djaposten natives of a village twenty miles away had come across gorillas in this way and killed several as they descended the tree. Several times I was able to follow gorillas closely enough to see the vegetation move as they descended the big forest trees that were bearing fruit. However, it was very difficult to approach gorillas under these circumstances, because they would be scattered about and one or another would invariably detect me or my companion before I had been able to find the particular gorilla I wished to collect.

Another time I approached a group of gorillas that we had been following most of the morning. There were monkeys feeding in the trees overhead and big hornbills that made a great deal of noise. The gorillas were just at the edge of a palm swamp when I came up with them and one half-grown one was up in a tree on our right. Directly ahead of me in the swamp were two baby gorillas, probably not more than fifty pounds in weight each, playing together on the ground as the adults were feeding near by. I waited, sure that within a moment one of the adults must come into view. Suddenly the one on our right became alarmed and started to climb down the tree, then dropped from a height of perhaps twenty feet or more, tearing down

DR. LEHMAN AND HIS MEDICAL BOYS.
THE NATIVES ARE TRAINED AS TECHNICIANS AND NURSES.

MOTHERS BRING THEIR BABIES, IN THIS CASE TWINS, TO THE CLINIC, USUALLY FOR TREATMENT, SOMETIMES JUST TO SHOW THEM OFF.

vines and leaves that encircled the bole of the tree. Malong rushed toward him as he dropped, but he made off through the underbrush without making an outcry. A few minutes later, however, he gave an alarm and the whole group hurried away.

A few days later Malong and I were hunting in this same locality. The ground was slightly undulating and the forest was heavy. We had been tracking a solitary gorilla for some time and we were both very keen to get this animal. On two or three occasions we had heard him beat his chest and we could tell from his movements and the size of his footprints that he was a large animal. Malong crawled just ahead of me and cut the vines with my knife, so that we might go forward without the slightest sound. We moved as quickly as we dared, for as the sun rose higher the leaves on the forest floor would dry and crackle On two or three occasions we got a momentary glimpse of the animal and from the springy way he stamped and bounded about he seemed to be full of life and vigor After about two hours I got a glimpse of him sitting in a tree fifteen or twenty feet above the ground, a small tree not more than ten inches in diameter. When I fired I was perhaps thirty yards away. He fell forward, I saw the outline of his upper part and thought I had shot at the back of his head. Later I was greatly disappointed to find that I had not seen his head but the back of his neck. The bullet passed through the upper part of his chest and right shoulder, which apparently had been raised at the time. This made it very difficult to embalm the animal.

It was just 11·30 when he was shot. Malong and I made a trail by compass back to camp. By hurrying we had reestablished camp near the gorilla by late afternoon, when I began embalming the animal. We camped there that night.

The following morning I sent a man to Djaposten for porters to cut a trail and carry out the gorilla. I worked all day on the animal, while every available man was employed on the trail. Several more men arrived that night from Djaposten.

When the gorilla was fairly well embalmed I sent Malong, Ze and seven other men to finish the work on the trail, while sixteen others made a *tepoy* or litter on which to carry the gorilla. When this was finished they began the journey back along the trail with the animal, while still other natives carried outfit. I went along with the gorilla for some time and then on ahead, cutting a tree here and there.

I arrived at Djaposten at 4:30 in the afternoon and sent Tsama and one or two others back to tell the porters that under no condition were they to stop but to keep moving until they got to Djaposten. Late that night I could hear chanting and realized that they were approaching. Finally at 1.30 in the morning they came in, bearing the gorilla.

Just before they arrived one man came limping along on a stick, holding up one foot and moaning. He dropped down beside me and showed me that he had a big thorn directly in the bottom of his heel. With a pair of pliers I was able to extract the thorn, which stuck nearly three quarters of an inch into the flesh.

I had never known a more surly lot of natives than this group when they set the litter with the gorilla on the ground. All they would say was, "You bin kill we for today." They had been carrying the gorilla, which weighed approximately three hundred and seventy-five pounds, on a litter made of green saplings weighing probably one hundred and fifty pounds more, from about seven o'clock in the morning until one-thirty the following morning, through swamps and over a fresh-cut trail where there were thorns, sharp sticks and driver ants.

A day or two later, in order to insure the perfect preservation of the animal, I had a woman dig a hole eighteen inches deep and six feet long in the floor of a hut. In this hole I put a canvas tarpaulin, which I waterproofed by painting it with paraffin wax. I then put the gorilla in there with embalming fluid.

While waiting in Djaposten I decided that an easier way to get gorillas would be to use native dogs. I thought native dogs were worthless until I tried to buy them. The first of these worthless animals cost me a hundred francs (about four dollars in our money); another, supposed to have been bred from a "whiteman dog," a hundred and fifty francs, which exactly equalled my cook's wages

ABBUP, A MAN WITH A SHAVEN CROWN, BECAME NURSE FOR MY BABY GORILLA.

for two months. The natives were very fond of their dogs and in bargaining for them I had to keep going up until I hit a sum which made them throw affection to the winds. It took some time to get these dogs to come anywhere near me. I kept them tied up about camp and fed them meat when that was available and other food that they would eat, such as bananas and papayas, until their fear of the white man was overcome. However, they were useless as hunting dogs because they were very much afraid of even wild pigs in the forest, and as soon as we got on the trail of a gorilla they all wanted either to walk right under my feet or to run back to camp. By the time I had proved to my satisfaction that these dogs were useless, the natives who had owned them and wanted them back had, of course, spent all the money and had no means of paying for them.

Natives told me that sometimes when a dog came near a gorilla the gorilla would simply stand still until he considered the dog within reach, when he would suddenly grab him and slam him on the ground This was the end of the dog.

After I had obtained the first gorilla in this region, natives told me of a place about eighteen kilometers along the road where there had been two or three villages, now deserted, so that the whole place was covered with second growth and gorillas found an abundance of food there I decided to investigate this locality, but on the morning of my departure I was surprised to learn that one or two of my best porters refused to go, saying that people that went there died of sleeping sickness. I had been told that there were no inhabitants and I considered that one was less apt to find infected tsetse flies there than about inhabited villages. When we reached there I found a deserted hut by the roadside, but all about was the densest type of jungle and the remains of a great many native houses that had tumbled down.

I had been there but a short time and was out early morning hunting with two or three natives when I was taken with fever. I could scarcely walk back to camp. I remember sitting in a camp chair beside the fire in a dark palm-thatched hut without windows. Late that afternoon my boy told me that they had heard a gorilla near by and that some of the natives said that this gorilla had crossed the road on many occasions. I took my gun and went out to the road. This was a motor road kept open by the French government so that one truck a week was able to go down to Lomie and keep in communication with the French official there. However, I soon found that I was unable to stand and after waiting a few moments went back into the hut. I spent the following day in bed, was unable to eat and had a fever of 105°.

That night I awoke and found the hut full of natives. Tsama told me that I had been talking, but they could not understand anything I said. This was about eight-thirty in the evening and I learned that an hour before, realizing that I was very sick, they had sent a boy to walk fifty-five miles to Nkol Mvolan to call Dr. Lehman. They said that if the boy was not lazy he should reach Dr Lehman by ten o'clock the following morning.

Later that same night I could hear people coming along the road wailing, as I had often heard them when one of their own was dead or dying Natives arrived and, still wailing, came right into the hut and stood around my cot staring at me. Several times I remember telling the boys to send them outside. It seemed that word had been carried along the road in one direction by the messenger to Dr. Lehman, in the other by some one else. The verdict of the natives was, as I heard them say when they left my bed. "This white man will die tonight and if he doesn't die tonight, he will die tomorrow." I knew only that I had a terrific headache, felt very weak and later was unable to sleep.

The following evening I heard the natives shouting outside, then there was the sound of a motorcycle. A few minutes later Dr. Lehman came in. He told me that the boy had arrived at his place at two o'clock that afternoon, having covered fifty-five miles in nineteen hours, without stopping. Dr. Lehman, having

ONE OF THE FIRST PICTURES OF MESHIE, A BABY CHIMPANZEE ONE YEAR OLD.

been told that I was seriously ill, had come immediately. He gave me an injection of strychnine and then hurried on to Djaposten, but returned in about an hour and spent the night in my hut.

There was a severe electric storm during the night and though this made the road bad, he said: "I must try to get you to Abong Mbang. I will go there to see the Commissaire and if their truck is there, I will come back immediately for you."

He left at daybreak and was back shortly after noon with the truck. The natives had to fold up my camp cot a little in order to get it through the door with me. Then we were out in the blinding midday light and the natives stood about while Dr. Lehman read a prayer. After that I was shoved into the truck.

That three-hour trip to Nkol Mvolan was about the worst ride I ever had. However, with the wonderful care and treatment given me by Dr Lehman at his home I was soon able to be up and about. Dr. Lehman tried to persuade me to return to the States, but I wanted to go back to Djaposten to try to get two more gorillas and some chimpanzees. I realized that I should be unable to hunt myself, but I intended to let the natives do the hunting and I would prepare the animals when they had secured them.

Dr. Lehman often remarked that my boy Tsama was anything but a cook, but he was the only one of the three boys I had brought from Yaoundé that was still with me. In the many months that I had been living about Djaposten I had lived to a large extent on the native food. Dr. Lehman said, in a later note advising me to return home: "It is not likely you can get better with the cook you have and the food available there."

While I was sick at Dr. Lehman's, Tsama told me one day that Nkoicha (Dr. Lehman's cook, who had been trained for years by Mrs. Lehman) was making cookies. On occasions when Dr. Lehman had come to Djaposten he had brought a tin of these cookies and Tsama knew that I liked them. I told him once that if he were a good cook, he could make cookies too. So now I told him to go and see how Nkoicha made cookies and later he told me he had the receipt written down

Back at Djaposten a few weeks later, one afternoon as I was starting out to hunt Tsama came to me and said, "Monsieur, I like for make cookies." Not wishing him to waste my supplies, I said, "Bring dem receipt." He brought it and I showed him how to divide it in order to make half the amount called for, for he did not know, for instance, what was a quarter or a third of a cup of ingredients. I returned from the forest just before dark and Tsama said with a smile, "Monsieur, cookies live for table." He followed me into the house, where I saw some cookies on a plate and others in a tin. He was eager to have me try them immediately and said, "Monsieur, chop 'em just now." I picked up a cookie and remarked, "Tsama, plenty fat live for dem cookies." He replied, "Ya, 'e be plenty fat." I then asked, "How 'e be plenty fat? No plenty fat live for dem receipt" He answered, "But for dem paper 'e live two receipt, one for cookies, one for doughnuts. For cook 'em I bin take receipt for doughnuts." In other words, they were boiled in oil.

The examinations that Dr. Lehman put me through showed that I had contracted sleeping sickness, two kinds of malaria, hookworm, ascariasis (infection with the roundworm *Ascaris*) and a number of other intestinal parasites. It is not surprising that an occasional white man, living practically as the natives do, should be affected with some of these things, for at the time of my visit in that district it was said that 65 per cent. of the natives had sleeping sickness, somewhat over 33 per cent. had malaria, and other diseases, such as syphilis, yaws and leprosy, were common. A great many natives were infected with *Filaria,* mostly of the type carried by the "osun" fly. One of my porters who contracted sleeping sickness seemed to suffer in about the same way that I did. Unfortunately he did not seem to respond to the treatment and died after four years.

It might be supposed that it was simply through carelessness that I had acquired

MESHIE PLAYING IN THE WATER WITH MPENIMAW'S CHILDREN AT DJAPOSTEN.

all these infections. It was not, for I was well aware of the dangers of infection and naturally had tried to avoid it. The four white men that originally composed our party had all taken quinine regularly during the entire trip as a prophylaxis against malaria, and none of the others suffered with it. But I had been in the neighborhood of Djaposten for a much longer period of time than I had planned and had run out of quinine for a short time before the extra supply arrived. It was during this time that I had my first attack of malaria. This seemed to weaken me so much that even after I got quinine the ordinary prophylactic dose did not prevent recurrence of the disease. It was necessary for me to take thirty grains a day for two months and then to continue with slightly smaller doses for two months more.

Of course in camp and in traveling we were always very careful to have our cots covered with mosquito netting and to search the inside of the net by means of an electric torch after we had tucked ourselves in. But naturally in hunting in the forest and being about camp in the early morning and evening we might be bitten by *Anopheles* without knowing it. This would be much less likely if one resided in a screened bungalow, which is the usual thing at the present time for people living in the tropics.

The boys are given to understand that all water for drinking purposes must always be boiled in order to avoid possible dysentery or certain types of *Filaria*, typhus or typhoid, etc. Nevertheless, Dr. Engle acquired dysentery while in the Belgian Congo, and though he received medical care there he was in-

MESHIE IN HER AMERICAN HOME

capacitated for many months after his return home

One may acquire such things as roundworms (*Ascaris*) if the boys do not use boiled water for washing dishes and also from using dish-cloths which have not been sterilized and which may have touched the ground, where the ova of these animals are to be found. *Ascaris* is a very common infection of children when they are crawling around on the bare ground. Sometimes a child will contain hundreds of these worms at one time. The adult worms are about a quarter of an inch in diameter and six inches long.

Hookworm is usually acquired either by direct contamination of food or water or by going barefooted, but one may also get it by wearing leaky shoes, which was my case. The extremely minute larval hookworm, coming in contact with the soles of the feet, is said to burrow through the skin and work its way into the lymphatics, which it follows to the thoracic duct and there enters the blood stream. In the blood stream it goes to the lungs, works its way through the lung tissue into the bronchi, then goes up the trachea and down the esophagus, passes through the stomach, and finally becomes attached along the walls of the duodenum, where it lives on the blood.

In the Cameroun the guinea worm,

which is a filarian reaching a yard in length, is rare. However, there are smaller filarians which are very common. Perhaps the most common is the eyeworm, *Filaria loa*. The microscopic stage of this animal is carried by a tabanid fly known to the natives as "osun," which is common, especially in dry weather. These filarians grow in the subcutaneous tissues and in the small veins and lymphatic vessels, especially of the extremities. This, I believe, is the organism that frequently causes elephantiasis. On a number of occasions when I assisted Dr. Lehman at operations these worms were found in the tissues. As a rule, however, they cause little inconvenience.

I saw no infections of tapeworm in the Cameroun, but I suppose they occur there, as one of the gorillas we killed in the Kivu was very heavily infected.

Yaws, syphilis and leprosy, though common, are no more likely to be acquired by white travelers in Africa than elsewhere. Yaws is very prevalent among the natives; the missionaries told me that the natives had regarded this disease much as we might regard measles, mumps or whooping cough, and apparently felt that everybody had to have it. But they had different names for the preliminary, secondary and tertiary forms of the disease and did not recognize them as stages of the same disease. Hundreds of lepers were being treated with an extract of chaulmoogra oil, which apparently cures this disease.

While at Dr. Lehman's home I saw a great deal of the wonderful work that he, like other medical missionaries, is doing. Great numbers of natives were examined for sleeping sickness, malaria, yaws and all sorts of other diseases and the infected persons were treated. Children who contracted sleeping sickness sometimes became very fat in the first stages of the disease; then as its effects progressed gradually began to waste away until some looked, as all the affected adults did, like living skeletons.

During the latter part of the time that I was in camp near Djaposten a couple of natives came in to my camp bringing a little chimpanzee, which I bought for three hundred and fifty francs (about fourteen dollars). She was a tiny little thing, not more than a year old and weighing about ten pounds. We called her Mon-A-Waa, Child-of-a Chimpanzee. Shortly after I returned to Djaposten she was playing with children and I heard them calling her Meshie-Mungkut (referring to her swaggering walk), and this name she retained. She became a great pet and very soon learned to sit beside me when I was having my meals in camp and to eat with a spoon and fork and follow me about wherever I went. When I drove a motor truck she sat beside me, but as I had no windshield the wind would blow in her face. This she disliked very much and consequently would keep her face so screwed up that absolutely every particle of skin was occupied by wrinkles.

To summarize briefly Meshie's later history, which has been written in many magazines in the United States and abroad, she returned to America with me and for about four years was the companion of my children in my home. She was so intelligent and learned so many things easily that a wider and wider circle of people became interested in her. I finally took her with me on my lecture tours to show what a young anthropoid was capable of learning in a human environment. Meshie made a great many friends during that time, and when she became too strong to be a safe playmate, we all parted from her with regret. She now has a good home and a happy life more in keeping with her natural state in the Brookfield Zoological Park of Chicago.

After spending about nine months in the forest near Djaposten I left there, having secured in that region two adult male gorillas, which I embalmed, as well as some chimpanzees and the skeletons of gorillas and chimpanzees which I salvaged from natives. I then returned to Yaoundé and made a trip in the direction of Akonalinga, where I secured another fine adult male gorilla.

Finally, having collected all the material originally planned by the expedition, I sailed for home on January 5, 1931.

In conclusion, I wish to express my deep appreciation to my friends of the American Presbyterian Mission in the Cameroun for their innumerable kindnesses, to the officials of the Cameroun for their courtesies and to the many natives who served our expedition faithfully.

POSTSCRIPT

By William K. Gregory

As both Columbia Unversity and the American Museum of Natural History stood for the protection and conservation of the gorilla, Mr. Raven made no attempt to exceed the modest quota allowed the expedition officially, although in previous years collectors had organized drives and secured great collections of gorilla skins and skeletons. Moreover, Mr. Raven had opportunity to witness the unfortunate effect, so far as the protection of the gorilla was concerned, of the demand for gorilla skulls on the part of scientists, to such a degree that white men as well as natives had in the past often done a profitable business in killing the animals and selling their skulls. The result had been a rapid decrease in the gorilla population, so that Mr. Raven, although by his record known to be a hunter and collector of the first rank, was compelled to hunt week after week in a desperate effort to come up with the nervous survivors of the race in this district.

Nevertheless, Mr. Raven's experience leads him to believe that while the gorilla is being rapidly exterminated in many localities, it may be actually increasing in others, as in the district northwest of Lake Edward, recently visited by Martin and Osa Johnson.

Dr. Engle, whom we left at Stanleyville when we started for West Africa, obtained the remaining records and photographs needed by Professor Morton, made many interesting observations in the hospitals and medical research stations along the Congo River and then returned to New York. He has summarized his impressions of the effect of white civilization upon native life in the *Columbia University Quarterly* for June, 1932.

Upon each of us Africa has set the seal of its magic. And whenever the fancy strikes me I can stand again in the forest on the mountains near Lake Kivu and hear the old gorilla utter his defiant scream.

ARBORETA, OLD AND NEW

By JOHN G. JACK
ASSISTANT PROFESSOR OF DENDROLOGY, HARVARD UNIVERSITY

THE question is often asked, "What is an arboretum, what is its purpose and its limitations?" Briefly it may be described as a collection of living trees and other plants having woody or ligneous stems above ground, that is, including shrubs and woody vines in addition to trees. Such a collection is understood to include an assortment of species brought together and planted for experimental, comparative or ornamental purposes, as distinguished from a plantation of one or few species which we designate as a grove. An orchard is really a form of an arboretum, but is usually understood to comprise trees planted for culinary or other directly economic products. Most arboreta are connected with or form parts of botanic gardens. The trees and shrubs which make up the collections may be scientifically arranged in sequence according to an accepted botanical classification or they may be grouped according to ecological factors or for their uses or with considerations of landscape or, as often prevails, in plantations where families and species are indiscriminately mixed.

While the Latin word *arboretum* is usually applied to the collection of trees and shrubs planted for comparative study or scientific purposes, the Latin word *arbustum* is sometimes used to designate the same thing and has essentially the same meaning. Thus we have the "Arbustum Americanum" of Humphry Marshall, published in 1785, one of the earliest botanical publications in America, by a native-born American, on native trees and shrubs known to that time. In a close analysis or differentiation, the word *arboretum* would be strictly applied to trees, while the term *fruticetum* would comprise shrubs and other woody plants which could not be classed as arborescent. But *arboretum,* as now most commonly used, includes shrubs and woody vines or climbers. However, a plant which grows as a tree in some situations may be reduced to a shrubby form in others, as in valleys or high, exposed parts of mountains, or a species of plant considered as a shrub may occasionally be found to become arborescent. Therefore the line separating a tree from a shrub may be stated as artificial, arbitrary and often difficult to establish. The definition of a tree differs somewhat with different authorities. The late George B. Sudworth, dendrologist of the U. S. Forest Service at Washington, stated "the definition of a tree is based on habit rather than size, and includes such woody plants as produce in nature a single trunk branching more or less above the ground." Plants which normally produce several stems from the same root are by this rule excluded, although their plural stems may sometimes attain large size, as in some species of alders, willows, etc. A scientific definition is that given by the late Professor B. E. Fernow, one-time chief forester of the United States and afterwards head of the forestry departments of Cornell and Toronto Universities. His definition is: "Trees are woody plants, the seed of which has the inherent capacity of producing naturally, within their native limits, one main erect axis bearing a definite crown, continuing to grow for a number of years more vigorously than the lateral axes, and the lower branches dying off in time."[1]

As it is not always easy to define

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[1] "Garden and Forest," Vol. 1, p. 410, 1888.

whether a species is entitled to be ranked as a tree or a shrub, so it sometimes is difficult to decide whether a plant usually classed as a herbaceous perennial should not be placed in the rank of shrubs or subshrubs, fruticose or suffruticose. For there are many so-called herbs which develop more or less ligneous crowns or short, woody stems above ground. Tropical or subtropical plants, like lantanas, heliotrope, etc., cultivated in northern gardens as annuals, may be substantial shrubs in their home environments. A native species which may appear as distinctly herbaceous in its northern range may develop a decidedly woody character in its southern limits or under peculiar ecological conditions. Thus there is really no sharp dividing line between trees, shrubs and herbaceous perennials. They are more or less interrelated and naturally should go as a unit for a botanic garden of hardy plants. This was the intent of the trustees who conveyed the Arnold fund, founding the Arnold Arboretum, to Harvard College, a trust which was never fully carried out, as the "herbaceous plants" stipulated were never included by the management.

With the early collections of trees there were usually associated shrubs, vines and herbs, the latter often being the dominant feature of what came to be known as "physic gardens," where special attention was given to medicinal plants and to those furnishing sustenance among such groups as monks or priests, who avoided the use of animal or flesh foods. In past ages, hundreds or thousands of years before the Christian era, such peoples as the Chinese and the Egyptians had their gardens which contained trees, shrubs and herbs, native or brought from distant lands, the best collections being about temples and cemeteries.

The formation of arboreta or collections of trees long antedates the records which have been handed down to us in the earliest writings which have been preserved. Very naturally the early selections and collections of trees, together with herbs, had to do with their direct utility, in a domestic sense, to human needs and desires, particularly those which afforded foods, spices and drugs. Southern Asia and Europe, now regarded as the natural garden in which originated the most useful species of our apples, pears, quinces, plums, almonds, cherries, figs, olives, oranges, pomegranates, furnished the tribes, usually regarded as semi-civilized, with a considerable variety in their diet. Thus collections of trees or orchards were first formed long before books were printed about them. Primitive names for operation or management, such as planting, pruning, grafting, etc., were in use long before they were written. Of course there are references to trees and other botanical objects in the early scriptural stories. From these it would appear that Solomon had collected a great variety of trees and other plants, forming an orchard or arboretum of fruit trees bearing edible fruits, and trees producing spices, as well as so-called "barren trees," as the Cedar of Lebanon (*Cedrus libanotica*). In early records there is frequent mention of palms, cypress, fig, olive, cinnamon, camphor and others, some of questionable identity. However, these are not recorded as forming definite groups or collections, arboreta or orchards.

The best available source of positive information concerning the trees known to the peoples or nations of antiquity is to be found in the works of Theophrastus, sometimes called the "Father of Botany," which give us the best history of trees known to the Greeks down to the third or fourth century before the Christian era. In his famous and exhaustive "History of Plants" Theophrastus described hundreds of kinds of plants, a large proportion of them with sufficient accuracy to enable modern botanists to identify and classify them in modern botanical terms.

It appears that, upon his death, Aristotle left his garden, in the Lyceum in Athens, to his pupil Theophrastus, and no doubt it was in this garden and arboretum that Theophrastus made many of the interesting observations recorded in his "History of Plants," of which there are translations in a number of languages. From the studies of botanical investigators into the identity of species of trees and shrubs known to Theophrastus it would appear[2] that he was acquainted with not less than 170 species, belonging to 53 natural groups, in addition to others which remain in doubt because of inadequate descriptions. Naturally a large proportion of these trees and shrubs were natives of Greece. The list includes a considerable number of great economic or historical interest, some of them brought from other regions. It is not claimed that all the species known to Theophrastus existed in the garden which he inherited from Aristotle, but no doubt a considerable proportion were to be found there. Aristotle is understood to have written two books on plants before the "History of Plants," but these did not survive the passing centuries and are forever lost. The "History of Plants," by Theophrastus, brings us some idea of what must have been the interest in trees before his time, never recorded in writing but passing down from generation to generation and exhibiting a surprising knowledge of plant variations in wild species or their cultivated forms. In various species he records that some superior forms have been named and that when these are grown from seed there is likely to be degeneracy. Besides seeds he speaks of propagation by cuttings, root cuttings and grafting, in terms which compare well with many of the essays by writers of the present day.

Only as a story do we know of the garden of Alcinous, which existed about 600 years before the time of Theophrastus, or a thousand years before the beginning of the Christian era. The record of this garden is essentially legendary. Homer has given us, in the "Odyssey," a picture of it. It probably existed and contained an assortment of trees, mainly those having an economic or esthetic value, and was considered wonderful in its time. Dioscorides, who lived and wrote his famous "Materia Medica" in the first century of the Christian era, gives us valuable information on the botany of his time and earlier, but of course this has no relation to any particular form of botanic garden or arboretum.

As already stated, these early collections were essentially of utilitarian interest closely related to general horticulture rather than of a purely arboricultural character, but they serve to show a trend to an interest in trees and shrubs which has finally developed into collections which are purely arboricultural or sylvicultural in purpose.

The Romans seem to have largely acquired their knowledge of trees from the Greeks, although numerous exotic species were introduced, so that an enumeration of the plants known to and introduced by them would show an acquaintance with most of the important species now recognized as native to Europe. Pliny in his famous "Natural History" gives us by far the best account of trees as known to the Romans in the first century of the Christian era. While he does not particularly enumerate trees as aggregated into collections or arboreta, he does give us an account of the most interesting kinds known to his countrymen. That trees, outside of orchard collections, were planted in groups or groves and highly considered, may be best shown by the following quotation from Holland's Translation of Pliny's "Natural History" (p. 357):

> "In old times trees were the very temples of the gods; and, according to the ancient manner, the plain and simple peasants of the country,

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[2] Loudon, "Arboretum et Fruticetum Britannicum," Vol. 1, p. 17.

> savouring still of antiquity, do at this day consecrate to one god or other the goodliest and fairest trees that they can meet withall; and verily, we ourselves adore, not with more reverence and devotion, the stately images of gods within our temples (made though they be of glittering gold and beautiful ivory), than the very groves and tufts of trees, wherein we worship the same gods in religious silence. First, the ancient ceremony of dedicating this and that kind of tree to several gods, as proper and peculiar to them, was always observed, and continues to this day. For the great mighty oak, named esculus, is consecrated to Jupiter, the laurel to Apollo, the olive to Minerva, the myrtle to Venus, and the poplar to Hercules.''

Thus we have the ancients of two or three thousand years ago dedicating trees to gods or individuals, a custom which has survived through the ages and which we follow in dedicating particular trees to persons or their memories on our arbor days or other special occasions. There is no doubt that in very early times cemeteries, temples and monasteries were the centers in or about which trees of various sorts were introduced, thus forming groves or primitive arboreta, though without such a considered purpose. Traveling priests and explorers brought home new trees and other plants from the lands they visited. Chinese records tell us that the Han Emperor Wu Ti, who lived 140–86 B.C., through one of his agents or missions sent to southern lands, was responsible for the introduction of walnut, pomegranate, grapes and other plants.[3] Some of these are now so naturalized or incorporated with the original Chinese flora that their true native home is a disputed matter. Some students of history now credit the Chinese with being the definite pioneers in the formation of botanic gardens made up of both herbs and trees, the latter persisting longer as remnants of what might have been called small arboreta.

We have unsatisfactory records of a Royal Garden and a garden about the temple of Karnak, in Thebes, Egypt, in the time of Thothmes III, about 1500 B.C., where palms and other plants were grown, but the variety was probably very limited and the place designed for pleasure rather than for more practical purposes. Very little is known of the gardens and botanical collections of the ancients for ten or twelve centuries after the dawn of the Christian era. From that time onward we know more definitely about the botanists and botanical works and the gradual development of collections for practical use or scientific study. Herbs dominated in the gardens of ''simples'' or ''physic gardens,'' as they were commonly called, which, in the fourteenth and fifteenth centuries were often attached to monasteries or to schools of learning where medicine was studied, particularly such institutions in southern Europe. One of the oldest and most famous of the collections of ''simples'' was the botanic garden at Padua, Italy, which was founded in 1545 and still exists on the same ground. Like most gardens of this era, the land area was small and precluded the admission of many trees.

Other famous gardens in Italy which were founded about the same time, or soon after that at Padua, were gardens at Pisa and at Bologna. The garden at Zürich was founded in 1560; in France the most famous were the gardens at Montpellier, in 1598, and at Paris in 1597, which is known to us now as the *Jardin des Plantes*. In this garden were grown many species of interesting introduced trees, though the collections of other gardens mentioned were mainly herbaceous. Important botanic gardens were established in Germany at Leipzig in 1579, Strasburg in 1620, Berlin in 1679. Sweden had an established garden at Upsala in 1657, and in Holland the garden at Amsterdam dates its foundation from 1682. While none of these contained definite arboreta, classed as such, they did contain interesting exotic trees of economic value and gave impetus to the formation of special and separate collections of woody plants. Among similar early gardens in Great Britain were the garden at Oxford, established in 1621, Chelsea in 1673 and Edinburgh in 1680. In Edinburgh there were rival gardens for many years, the remaining present one being under the University and Medical School. Various public and private arboreta were established in the following years and through the eighteenth century, both in continental Europe and in Great Britain. Some of the public or semi-public establishments have ceased to exist and private collections have mostly been lost through lack of interest by generations which succeeded the founders.

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[3] E. Bretschneider, ''Botanicon Sinicum,'' Part 1, pp. 24–25, 1881.

Many small private collections of trees and shrubs were established in Great Britain during the eighteenth and nineteenth centuries and some of these are well worth while visiting to-day. In the south of England and Ireland there are growing in the open air hundreds of species of trees and shrubs which it is impossible to grow in northeastern North America.

The Royal Botanic Garden at Kew, or Kew Gardens, as we familiarly call them, form the center from which has emanated much of the inspiration which pervades plant enthusiasts and arboriculturists in all civilized parts of our globe. The beginning of Kew Gardens may be dated as from 1759 or 1760. About that time Princess Augusta, Princess Dowager of Wales, being much interested in botany, had set apart about nine acres of the Royal Garden attached to Kew House for the purpose of forming a physic garden, and an arboretum to contain all the then known hardy trees and shrubs. This appears to be about the first definitely designated and important "Arboretum." In 1772, George III inherited the Kew House property and united the gardens of the palace with those lying adjacent and so made up the extensive territory now known as the Royal Botanic Gardens at Kew.

Sir Joseph Banks was chosen to administer the garden, which he did for 48 years, during which time it prospered greatly and gained vast influence in the botanical and horticultural world through exploration and experimentation. Following the death of Sir Joseph Banks in 1820, there followed a quarter of a century when Kew fell in efficiency, but after the appointment of Sir William Hooker to the directorship, in 1841, the institution soon resumed a commanding position in the botanical world, which it still holds. No botanical institution has been so indefatigable in exploring all parts of the globe for plants of economic or scientific interest and in distributing its acquisitions among botanic garden stations in the widely scattered British colonies and to botanical institutions wherever founded. The great herbarium is the most important in existence and with this are various museums for the illustration of phases of plant life. But the Botanic Gardens and Arboretum, covering 288 acres, are the special objects of interest to all students of living plants. Here, in a latitude which corresponds to that of southern Labrador or the northern tip of Newfoundland, may be found the largest collections to be found within temperate or subtropic zones. That such a collection is possible in the latitude of London is due to the modifying influence of the Gulf Stream which originates in the tropic coasts of America and the Mexican Gulf. Here about 20,000 species and varieties of trees, shrubs and herbaceous plants may be found, labeled and with scientific arrangement whenever practicable. Notwithstanding its large area it is interesting to note that, excepting wheeled chairs propelled by man power, no vehicles are allowed within the gates of Kew, a rule which adds much to an atmosphere of restfulness and the peace of those who resort to the place for observation and study.

The proximity to London, with its smoke and gases, which are not conducive to the best growth in plants, has recently caused the authorities to plan and plant a new arboretum, for conifers at least, much farther from the city and it is conceivable that the time may come that the best part of Kew will be found in new quarters.

Among the tropical or subtropical arboreta established or aided by the British Government, through Kew, may be mentioned the gardens at Jamaica, at Trinidad, in Hongkong, in New Zealand, Australia, India, Ceylon and South Africa. In all these the tree collections are of importance and enable the student to obtain some acquaintance with trees and shrubs of the tropics and subtropics. The garden at Peradeniya, in Ceylon, is especially noteworthy.

Throughout Great Britain there are many small private collections of trees or arboreta, the owners of which got their inspiration from Kew, although much was accomplished through private initiative much earlier than the foundation of the now most famous institution. Space does not allow of mention of any of these.

In Germany the Botanic Garden in Berlin was founded as early as 1679, in the heart of the city, but with an area so small as to preclude any considerable collection of trees. But about 40 years ago the formation of a new Garden at Dahlem, to replace the old Garden in Berlin, was undertaken and was practically completed in 1909. Without doubt this is the most important, next to Kew Gardens, of botanical institutions in temperate zones. The area is only about half that of Kew, but every detail has been elaborately worked out for the plantations, for research and for study. Landscape effects have been strictly subordinated for those of a practical nature, unlike Kew, where vistas and pleasure have been considered as well as development along scientific lines. The Arboretum at Dahlem comprises an area of about 50 acres, the trees and shrubs being planted singly to give each species a full chance to develop its characteristics or peculiarities. The number of hardy species which it is possible to grow at Dahlem is decidedly less than is possible near London, due to the much colder winters in the region of Berlin. Some of the group collections are already the most complete in existence and the institution is a Mecca for arboriculturists, horticulturists and working botanists. Almost every forest school in Germany has its little arboretum, private collections are numerous, and even the most progressive commercial nurseries have instructive groups of trees and shrubs.

The arboretum at Les Barres (Loiret) France, 75 or 80 miles south of Paris, begun in 1825 by the famous horticultural firm of Vilmorin, was bought by the French government in 1866 and is now known as the Arboretum National de Barres It stands as the best collection of trees in France. In the vicinity is the Fruticetum Vilmorinianum, forming the finest collection of shrubs in the nation. The Les Barres establishment is now used by the state as a school of silviculture.

It is not here possible to more than mention the garden at Leningrad (St. Petersburg), founded in 1713, where Maximowicz, Regel and others did so much for the study and introduction of really hardy trees and shrubs, and of other botanic gardens widely distributed in distant parts of the Soviet Republics where small collections of trees may be found.

While most of the arboreta of the past were naturally associated with or adjuncts to botanical gardens, there were some cases where trees were given first attention. As already intimated, some of the collections have fallen into disorder because of lack of endowment or the fact that later owners did not have the same interests as the founders, or sometimes conditions of population or of climate or environment may so change as to make abandonment wise or necessary. Such untimely ends are always likely to occur, whether the enterprise is under private or public ownership.

It may interest readers to know that in China at the present time several arboreta of considerable area are in process of development. Chinese students who have studied in the United States and in Europe are enthusiastic promoters of and workers for the enterprises which often receive generous, though inadequate, help from public funds.

While the Dutch in Holland have done much in tree study, it is the Botanic Garden at Buitenzorg, Java, founded in 1817, which is world famous and without any doubt forms the most extensive and complete botanical establishment in the tropics. Covering an area of much more than a thousand acres, there has been assembled a bewildering collection of plants unequalled by any other institution of its kind. Here may be found thousands of species of trees and shrubs from all parts of the tropics, so that nowhere else may the student of botany get such a comprehensive view of the plants of hot climates. Through research the botanical achievements have been great, and the encouragement given to the cultivation of cinchona (quinine), cocoa, coffee, rubber, sugar, spices and other economic products has been of very great value not only in the Dutch East Indies but throughout the tropics where such crops are grown.

Excepting those in the West Indies, which have been mentioned in connection with Kew and the British Government, no reference has been made to tropical gardens or arboreta in the New World. In the garden at Rio de Janeiro, in Brazil, founded in 1808, there is a good opportunity to study palms and other trees in a fine state of development, and the gardens of Santiago, in Chile, and at Buenos Aires, Argentina, have long been well known.

In the Panama Canal Zone an attempt is being made to introduce a large assortment of useful and ornamental trees, and the result should be an interesting arboretum.

While we know little of the ancient history of the peoples of America, it has been authoritatively stated that in Mexico, at the time of the Spanish Conquest, the Aztecs had gardens well worthy of the name. These gardens of the Aztecs were clearly of native origin and in no way connected with similar developments in the Old World. In the *"Nova plantarum animalium et mineralium Mexicanorum historia"* of F. Hernandez, published in 1651, the oldest published natural history of the New World, we have illustrations and Aztec names of trees and shrubs and other plants, many of which probably became known, or better known, to Hernandez through these gardens. Montezuma was known as a patron of gardens. Among other references to Mexican gardens of that era the following description is interesting—"Sandoval took up his quarters in the dwelling of the lord of the place (Chalco), surrounded by gardens, which rivalled those of Iztapalapan in magnificence, and surpassed them in extent. They are said to have been two leagues (about five miles) in circumference, having pleasure houses, and numerous tanks stocked with various kinds of fish; and they were embellished with trees, shrubs and plants, native and exotic, some selected for their beauty and fragrance, others for their medicinal properties. They were scientifically arranged; and the whole establishment displayed a degree of horticultural taste and knowledge, of which it would not have been easy to find a counterpart, at that day, in the more civilized communities of Europe. Such is the testimony not only of the rude Conquerors, but of men of science who visited these beautiful repositories in the day of their glory."[4] This was in 1521, while the earliest botanic garden in Europe, at Padua, was not established until 1545.

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[4] Prescott's "Conquest of Mexico," Vol. 2.

In North America there are now listed between forty and fifty collections under the name "arboretum" and at least a hundred other public and private or semi-private collections which, passing under the classification of "botanic garden," include a fair representation of trees. A list of such institutions was given in the *Arnold Arboretum Bulletin of Popular Information* for September, 1931. In that list Pennsylvania is credited with a larger number than any other state, 21 being listed. What appear to be the oldest attempts to form tree collections in North America, after settlement by Europeans, originated in that state. They were small in area but were valuable and instructive for their time. In 1728 John Bartram, a Quaker, known as a farmer, traveler and botanist, secured a piece of land on the banks of the Schuylkill River about three miles from Philadelphia and there established what became famous as Bartram's Garden. There he brought together a number of American trees collected during his travels and also, through correspondents, introduced a number of species of trees from the Old World. He was instrumental in first introducing numerous American trees into England. After his death in 1777 the garden was allowed, by various owners, to gradually decline until 1891, when it was bought by the city of Philadelphia and included in the park system. Few of the trees planted by Bartram now exist.

Humphry Marshall, already referred to as the author of the "Arbustum Americanum," a relative of John Bartram's, about 1773 planted a collection of trees near West Chester, Pennsylvania, only a few of which are now living. Other interesting collections have been planted in the region of eastern Pennsylvania either privately or in connection with tree nurseries of a commercial nature. Perhaps the most promising is the Morris Arboretum, originally privately established and now under the management of the botanical department of the University of Pennsylvania.

About 95 years ago H. W. Sargent, upon an estate known as Wodenethe, near Fishkill-on-the-Hudson, New York, planted a large variety of native and foreign trees, with conifers prevailing, which became a widely known private arboretum and without doubt did much to promote the public interest in trees and in landscape art.

It is impossible to enumerate in this article the many smaller arboreta started within the past half century and which have been of much help to students of trees. Some of these collections still exist and are growing, others have performed their educational mission and have fallen into decay.

Inhabitants of the far north find an instructive arboretum at the Central Experimental Farm at Ottawa, Canada, which has acted as the parent of subsidiary small experimental collections at numerous stations from Nova Scotia to British Columbia. This central Canadian station may be classed as a National Arboretum. Such an institution has been advocated for many years for Washington, in the District of Columbia, but, although a large tract of land has been acquired, money for construction work has not been appropriated. The site is good and such an establishment in the national capital should become an important educational feature. Like the British Kew Gardens such an institution, with the cooperation of the Department of Agriculture and the National Herbarium, and other advantages, might well become a Mecca-like center to which government experiment stations, colleges and others forming arboreta might naturally turn for help.

Existing arboreta scattered over the country vary in scope from that which specializes only in one family or genus and their variations, as the so-called "Hemlock Arboretum," to those of such a broad scope as to include all kinds of ligneous plants which may be grown in the particular region and climate in which the establishment is located. Many of our colleges and agricultural experiment stations have now established arboreta as a part of their educational equipment, and parks and the U. S. Forest Service have developed and are developing collections of very decided use in furnishing instruction to the public or as testing grounds of the comparative adaptation and values of trees in forestry or park plantations. A good example of what parks may do may be cited in the case of the Rochester (N. Y.) City Parks, which contain one of the finest named collections of trees and shrubs to be found in our cold temperature zones. Golden Gate Park in San Francisco boasts a very fine and extensive collection of trees and shrubs adapted to the Pacific coast in California.

Among arboreta connected with forestry work or silviculture, we can here only refer to the Wind River Arboretum, Columbia National Forest, near Carson, in Skamania County, Washington, about eight miles north of the Columbia River and located at about 1,200 feet above sea-level. Here possibly useful species of trees, chiefly conifers, from all temperate parts of the globe are being tested especially for silvicultural or reforestation purposes. The number of species grown is limited chiefly to those of known value or probability of adaptation, so that the student of dendrology and forestry may see the actual behavior of species under the prevailing conditions of the region in which they are grown. Although only started in 1912 upon a few acres, the experiment has proved of real interest and will be enlarged as more area is required. It is here referred to as an illustration of what is now being attempted throughout the country.

In recent years in the eastern United States there have been several large undertakings to build up extensive collections of trees and shrubs. Perhaps the most important and most promising is the Morton Arboretum at Lisle, Illinois, about twenty-five miles from Chicago. This was founded by the late Joy Morton in memory of his father, J. Sterling Morton, one time U. S. Secretary of Agriculture. It was begun in 1921, and every effort is being made to create one of the most complete institutions of its kind in the country.

A still more ambitious enterprise is that which is being planned for the vicinity of Cleveland, Ohio, and is tentatively known as the Holden Arboretum. These last two arboreta are in almost exactly the same latitude and both must come under the influence of the Great Lakes, so that experiments and tests carried on by two such museums of living plants should prove interesting and provide valuable practical and scientific data.

The arboreta which form part of the collections of the New York Botanical Garden and of the Brooklyn Botanic Garden, which has the advantage of proximity to Prospect Park, have certainly been important as educational features of these establishments, although their existence goes back only two or three score years.

Many of the foregoing institutions, besides others not here mentioned, unquestionably derived inspiration and much help from the Arnold Arboretum, of Harvard University, in Boston, which may well be considered as having inspired much of the interest in dendrology and arboriculture in North America during the past fifty or sixty years.

As much has been written about this institution and its work it is not necessary to recapitulate its past history here in detail.[5] The property of Harvard

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[5] See "The First Fifty Years of the Arnold Arboretum," by Professor C. S. Sargent, in *Journal of the Arnold Arboretum*, Volume 3, January, 1922.

University, an agreement was made with the City of Boston to open it to the public provided that the city build and maintain roads and give police protection, leaving to the college full control of all plantations and experimental work over the more than 250 acres of ground. Seed collecting and plantings in nurseries were begun in 1872, but various delays did not allow of any of the permanent, systematic plantings until the spring of 1886. The Arboretum was fortunate in enjoying exceptional opportunities for the collection of seeds, both North American and from the Old World, and it soon became the medium of extensive exchanges of plant material with institutions and interested individuals at home and abroad. It has been instrumental in introducing into cultivation many hundreds of species of trees and shrubs hitherto unknown in American gardens and its influence in that way certainly was important and far-reaching in enriching plantings in parks and gardens.

Besides such activities the Arnold Arboretum through its educational propaganda by members of the staff and working force has, in the past, exerted a powerful influence in arousing and holding a public interest in arboriculture, horticulture, landscape and park development, and in forestry. For ten years, between 1888 and 1897, the weekly *Garden and Forest,* edited by Professor C. S. Sargent, was probably the most influential medium of the time in arousing an interest in plant life as related to our gardens and forests. But many other scientific publications have emanated from the institution and it has been a study and research station for a large number of American and foreign students in dendrology and forestry.

With the establishment of so many new arboreta and botanical gardens throughout the country, the burden once carried by the Arnold Arboretum has become distributed and it may be that it accomplished a greater public service in the past half century than it is likely to do in future, although it now enjoys a vastly increased income as compared with the meager $3,000 a year from the Arnold legacy when work was begun in 1872. A dream of those who have worked for the institution is a chain of stations in various parts of the country with differing climatic and ecological conditions, so that a better knowledge may be gained of trees and shrubs adapted to the various regions. Already such a station has been well established at Soledad, near Cienfuegos, Cuba, where the Atkins Institute of the Arnold Arboretum is intended to have a representation of useful and otherwise interesting trees and shrubs adapted to the tropics or subtropics of Cuba. It is hoped to specialize in the bringing together of as many as possible of the West Indian or Central American trees, many species of which are rare or fast disappearing. Cuba is particularly rich in species of palms, some of which are widely scattered and little known. This group is a difficult one to study and this may be best done by bringing living specimens together for comparison. Not all kinds of palms will thrive in the climate of Cuba, but already more than 225 species and varieties of palms have been brought into cultivation in the Soledad garden. This station is an illustration of what may yet be established in other parts of continental America in connection with the Arnold Arboretum with its fine library and extensive herbarium in which special students may carry on research supplementary to their studies in living collections.

Under other private, college or government auspices such work is already being done in boreal and in warm temperate localities, on the Atlantic and Pacific slopes, on our plains and under such xerophytic conditions as prevail in Arizona.

THE PROBLEM OF THE ORIGINS OF ALCHEMY

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A NUMBER of recent publications on the origins of alchemy, in particular those of Hopkins,[1] Barnes[2] and Partington,[3] make it apparent that a reconsideration of the whole matter is desirable and that a careful definition of the problem is necessary.

The name of alchemist to most people probably suggests a medieval figure of a man surrounded in his laboratory by the apparatus of chemistry, furnaces, retorts, crucibles, bottles, specimens of animal, vegetable and mineral oddities, an aged man perhaps, blackened by the soot of his labors and still fired with the enthusiasm of his fantastic quest for an elixir of long life or of immortality or for a philosopher's stone by which base metals might be converted into gold and silver. The picture is plainly the picture of a chemist who is devoting his chemistry to very special purposes. A man might conceivably be a chemist, but, if he were not applying his art to the search for the elixir or for transmutation, he would be no alchemist. Another desiring the same results, but without knowledge or practice in chemistry, might perhaps seek to attain them by fasting or by prayer, by systematic deep breathing or by magic ceremonials. He also would be no alchemist. The desiring of the objectives is not enough, nor is the effort to procure them unless it be by chemical means. We therefore conceive alchemy to be the search or the effort, whether successful or not, by chemical means to prepare a medicine of longevity or immortality, or by chemical means to prepare authentic noble metal from base metal or both—the pursuit of either or both of these objectives by chemical means. The beginnings of that search are the beginnings of alchemy.

This conception of alchemy is in agreement with ancient usage. The Alexandrians and Byzantines had χημια, but *al-kimiya* first appeared in Europe among the Arabs about the eighth century. The medieval Latins made clear distinction between *chemia* (or *chimia*) and *alchemia* (or *alchimia*), the latter term at first meaning chemistry of Arabic origin but soon taking on precisely the meaning which we have assigned to it in the foregoing, being reserved for the special quests by which, as it happens, Arabic alchemy was characterized and distinguished from the chemistry of the Alexandrians and Byzantines. Writers of the time of Paracelsus discussed the solid contributions to chemistry which were made by the alchemists. The distinction appears clearly in the writings of Boyle and of Boerhaave, but there were in their time, as there have been since, those who failed to distinguish sharply between alchemy and the ideas and practices which were often but not always necessarily associated with it.

While all writers on the history of chemistry seem to be in agreement with our conception of alchemy, and many have indeed specifically defined it as we have, some of them have frequently proceeded in their writings to use the name in other senses and have thereby increased the difficulties of discovering the origins of the art. Berthelot has called alchemy a pseudo-science, and has stated that its relation to the science of chemistry, which he says grew out of it, is the same as that of astrology to astronomy.

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[1] Arthur John Hopkins, "Alchemy, Child of Greek Philosophy," Columbia University Press, 1934.

[2] William H. Barnes, *Nature*, 135: 824, 1935.

[3] J. R. Partington, *Nature*, 136: 287–288, 1935.

Alchemy has been called primitive chemistry, and any chemistry which is ancient enough or sufficiently crude has been called alchemy. Documents of practical chemistry, like the Leiden and Stockholm papyri, and documents of cosmology, like the Emerald Table of Hermes Trismegistos, which contains no chemistry whatever, have been described as documents of alchemy. The "Introduction," which constitutes the first volume of Berthelot's great "Collection des Anciens Alchimistes Grecs,"[4] is identical with the material which constitutes the large part of his "Introduction à l'Etude de la Chimie des Anciens et du Moyen Age."[5] Berthelot used the two names indifferently, and reached conclusions which do not apply strictly either to chemistry or to alchemy.

The history of man divides itself naturally into epochs which correspond to man's increasing ability to apply chemistry to practical purposes. Stone Age man made use of the materials which nature provided and of objects which he was able to fashion from them by physical means. His materials included stone, wood, clay, etc., meteoric iron and native gold, silver and copper. After he had mastered fire, he began to carry out chemical processes in the smelting of ores. The sequence of the chemical ages commenced—the Bronze Age, the Iron Age, the Steel Age and the present Nitrogen Age. The old mythologies tell of metallurgists—Tubal Cain, Hephaistos-Vulcan and the dwarfs who lived under the earth and made the hammer for Thor. A discussion of the beginnings of chemistry is a discussion of the beginnings of civilization wherever and whenever they occurred.

Chemistry accomplished marvelous things. New and altogether surprising phenomena were discovered. It seemed no extravagant hope that chemical processes might lead to the elixir and to transmutation. Alchemy arose at a time when much chemistry was already known. It was not pre-chemistry. It arose in consequence of a pre-existing knowledge of chemistry.

The same conclusion follows from our definition of alchemy as the search for the elixir and for transmutation by chemical means. *Without* the means, how could one conduct the search *with* them?

If the ancient Egyptians considered gold to be an elixir of life, as supposed by Elliot Smith and by Moret,[6] or if they actually used it for that purpose, we are not therefore justified in concluding that they were engaged in the practice of alchemy. To fulfil our definition they must have been trying to make real gold artificially by chemical means, as the Chinese were trying probably as early as the third century B.C., in order that they might use it as a medicine of longevity or of immortality. The Latin workers who later attempted by chemical means to make gold potable, and hence of readier application as an elixir, were alchemists pursuing one of the two prime objectives of their art. They would equally have been alchemists if they had been trying to prepare an elixir by the chemical treatment of limestone or of iron or of barley malt or of any substance whatever.

Primitive man, thinking about the world, early developed theories, at once scientific and religious, cosmological and epistemological, physical and metaphysical, which supplied him with a general explanation of the order of things, a background upon which special theories for special purposes were later superstructed. The oldest such doctrine, almost universally prevalent, seems to have been that of the "two contraries," of the father god or positive principle, hot, active, fiery and light, and the mother goddess or negative principle, cold, passive and heavy, by the interaction or combination of which all things in the world were produced and ordered.[7] In due course the general doctrine was applied to the explanation of chemical phenomena—by Zosimos and others. Chemical theories arose. The beginnings of these chemical theories are something that may be discovered and discussed, but they are not the beginnings of alchemy.

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[4] Paris, Steinheil, 1888.

[5] Paris, Steinheil, 1889. 268 pages out of 301 pages of text.

[6] Elliot Smith, "The Ancient Egyptians," London, 1923, pp. 205, 206; Moret, "Le Rituel du Culte Divine," Paris, 1902, cited by Wiedemann, "Das alte Ägypten," Heidelberg, 1920, p. 343; both cited by Partington, "Origins and Development of Applied Chemistry," London, 1935, p. 23.

The primitive doctrine of the "two contraries" prevailed in Egypt and in Mesopotamia at a very early time. When chemical and alchemical matters aroused interest and became subjects of thought and discussion, they were of course discussed in the language of the prevailing idea-system. An account of the application of the fundamental doctrine of the two opposites[8] to the description of chemical phenomena constitutes a veritable cross-section of the history of chemistry, an account of the sulfur and mercury of Zosimos and Jabir, of the phlogiston of Stahl and Scheele and Priestley, down to the beginning of the nineteenth century. The Leiden and Stockholm papyri, recipe books of practical chemistry of the third century, make no reference to the doctrine. Other treatises of about the same time are pervaded by it, and from that time onward the association between chemistry and ideas based upon the doctrine of the "two contraries" is well-nigh invariable —an invariable but a one-way association, for the ideas in question are always found where chemical matters are being discussed, but chemistry is not invariably present, as scholars have failed sufficiently to note, in all discussions which are based on the ancient doctrine. Documents which contain no chemistry—the Emerald Table of Hermes Trismegistos is a notable example—have mistakenly been regarded as documents of chemistry and even of alchemy, because they are clearly pervaded by the doctrine upon which so many chemical discussions are based.

The doctrine of the "two contraries" appears in discussions of a non-chemical character, it appears in third century Alexandrian chemical texts and in Chinese alchemical treatises of the second century and later. The Alexandrians and the Chinese alike had the same general dualistic background of nature theory, idea-system or world concept. Indeed, the Chinese *Yin-Yang* was probably an importation from Egypt or Mesopotamia, although the matter is not important at the present point in our argument. The Alexandrians, interested in the chemical processes of smelting the metals, of alloying them and of altering their colors in various ways, described their experiments and speculations, naturally enough, by means of a vocabulary which arose out of the dualistic theory. The Chinese alchemists, interested, as we shall see, in the chemical preparation of an elixir and in actual transmutation, likewise spoke from the point of view which prevailed among them. It is natural that the language of the Alexandrian chemists should resemble that of the Chinese alchemists, all the more so as it was the practice of the time to name the reagents obliquely and to maintain secrecy by describing the processes in parables or in fantastic language. We have elsewhere pointed out[9] the similarity between certain passages of the Chinese alchemist, Wei Po-yang, and passages of Zosimos and other Alexandrians—from which we wished to conclude merely that the Chinese and the Alexandrians both possessed a dualistic scientific background and that both had the mental habits of their times. From the evidence alone of this similarity, we are not willing to conclude, as Partington[10] wishes to do, that the Chinese and Alexandrian treatises and traditions are necessarily related at all closely or that one is derived from the other. Nor does the similarity of language prove a similarity of aim. The aim of the author is to be discovered in his statements. Because Wei Po-yang was writing of alchemy, it does not follow at all that Zosimos and the Alexandrians who used a similar language were also writing of it. If they were, it ought to be possible to find them saying so.

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[7] For a fuller discussion of the distinction between the really chemical and alchemical doctrines on the one hand and, on the other, the general cosmological and scientific background on which they stand, see the article on "Primitive Science, the Background of Early Chemistry and Alchemy," *Jour. Chem. Education*, 12: 3–10, 1935.

[8] Including, of course, its expansion into the two pairs of contraries of Aristotle and of the pre-Mosaic cosmologists.

[9] In the introduction and notes which accompany *Lu-Ch'iang Wu's* translation of the "Ts'an T'ung Ch'i" of Wei Po-yang, *Isis*, 18: 210–289, 1932.

Quite another matter it is when we find that the "Speculum Alchemiae" of Roger Bacon describes a process for the preparation of the philosopher's stone identical with that which Wei Po-yang more than twelve hundred years earlier described for the preparation of the pill of immortality.[11] This is real evidence of the probable origin of European alchemy.

The ancient Egyptians had so many things that it would be extraordinary if they did not have alchemy. Partington[12] states that "Napier says the idea prevailed in ancient Egypt that gold was the only true metal, other metals being different varieties of and convertible into gold, an idea which persisted as alchemy, but gives no authority for this statement; the idea is almost the same as that of the Arabian alchemist Abu'l-Qasim al-Irâqi in the thirteenth century A.D." We must scrutinize the language carefully. If the Egyptians believed that other metals are artificially convertible into gold, then they believed in the truth of alchemy. Perhaps they believed, as the medieval alchemists did, that base metals in the earth are constantly undergoing a natural and spontaneous change or growth by which they are slowly converted into gold. The same idea appears in the writings of "Liu An" or "Huai-nan-tzŭ" (died 122 B.C.), the first Chinese who is supposed to have written on alchemy, by tradition a master of the art. Johnson,[13] says that he taught that "gold grows in the earth by a slow process, and is evolved from the immaterial principle underlying the universe, passing from one form to another up to silver and then from silver to gold." The belief that the conversion can be accomplished artificially is belief in the truth of alchemy, and the effort to bring it about by chemical means is the practice of alchemy. But there is at present no evidence that the ancient Egyptians were practicing the art. Indeed, the Alexandrians who had access to much of the culture of ancient Egypt do not seem to have practiced it.

In his recent book on "Alchemy, Child of Greek Philosophy," Professor Arthur John Hopkins defends two principal theses, first, that the Alexandrian chemists, or alchemists as he calls them, were interested in imitating the precious metals by alloying or by staining or tincturing base metals to the appearance of the noble ones, that they were interested in the color more than in the substance of the metals, and second that the theoretical basis of Alexandrian and of later European alchemy was derived from Greek philosophy, that alchemical theory arose out of the impact of the practical chemical arts of the Egyptians upon the speculative philosophy of the Greeks. The two points are not dependent upon each other. The first is one which Professor Hopkins has set forth clearly and convincingly in a number of earlier articles.[14] It appears to be fully established—and we shall devote no more space to it in the present paper, except to mention that the Alexandrian chemists, practicing the imitative arts of the earlier Egyptians, were well aware that their products were not the genuine materials. They no more thought their yellow alloys and tinctured metals to be real gold than we think German silver to be real silver or artificial silk to be identical with the product of the silkworm. If Hopkins's view is correct, then the Alexandrians were not practicing alchemy. There still remains open the question of the origins of that indubitable alchemy which the Arabs possessed and transmitted to the medieval Latins.

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[10] Partington, *Nature*, 136: 288, 1935, says: "Many points of contact between these and other statements in the Chinese treatise and in the Alexandrian treatise can be found, so that the general conclusion of Dr. Wu and Professor Davis, who do not favor much relation, is scarcely borne out by detailed examination: they cite, in fact, several parallels with Zosimos in the notes and could have cited a good number more. These notes suggest parallels with later works on European alchemy . . ."

[11] *Isis*, 18: 243, 277, 1932.

[12] Partington, "Origins and Development," etc., p. 27, citing Napier, "Manufacturing Arts in Ancient Times," Paisley, 1879, p. 4.

[13] Johnson, "A Study of Chinese Alchemy," Shanghai, 1928, p. 75 *fn.*

With the second of Professor Hopkins's contentions we are unable to agree. Since the Alexandrians had no alchemy, it seems improper to suppose that they had alchemical theory. They had chemical theories for their practical chemistry. They believed in the unity of matter, but it can not be maintained that that notion was original with the Greeks. They adhered to the idea-system of their time. For the interpretation of chemical phenomena they had theories which were based upon the ancient doctrine of the "two contraries." And that doctrine is much older than Greek philosophy. Having arisen in the darkness before known history, it gave rise to a persistent and uninterrupted stream of thought which flowed around, through and past the glory of Greek philosophy and dominated chemical thought—perhaps to the present—certainly to times as recent as those of Lavoisier and the Chemical Revolution.[15]

The medieval alchemists derived their alchemy from the Muslims, and our question becomes—Whence did the Muslims derive their alchemy? Evidently not from the Alexandrians. But they did derive from the Alexandrians the chemical art of changing the color of the metals, and apparently combined that art and its accompanying theory with the alchemical tradition, of the elixir and of real transmutation, which they derived from some other source. Both traditions are found in the Arab treatises and in the Latin writings which are based upon them, often confused but frequently in such fashion that they may be distinguished. In the tract "de Alchemia," which is ascribed to Albertus Magnus, the author says concerning alchemy that "through this art metals which are corrupt and imperfect in the mines are brought to perfection."[16] He says: "I began more diligently to keep vigil with the decoctions, sublimations, solutions, distillations, cerations, calcinations, and coagulations of Alchemy, and with many other labors, until at length I found the transmutation to be possible into sun (gold) and moon (silver) which are much better than any natural material in every test and hammering."[17]

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[14] Hopkins, SCIENTIFIC MONTHLY, 6: 530–537, 1918; *Cairo Scientific Journal*, 11: 159–169, 1923; *Isis*, 7: 58–76, 1925; "Studien zur Geschichte der Chemie, Festgabe für Edmund O. von Lippmann," Berlin, 1927, pp. 9–14.

[15] Nierenstein, reviewing Hopkins's book in the *Journal of the American Chemical Society*, 58: 539, 1936, says: "There is no doubt whatever that the idea of transforming one form of matter into another is the logical consequence of Aristotle's philosophy of matter" (with which we agree fully), but adds—"and that the whole idea of ancient chemistry is imbued by the philosophy of Aristotle" (which is not the case by any means).

[16] "Theatrum Chemicum," Vol. II, p. 488, Ursellis, 1602.

[17] *Ibid.*, p. 486.

Although one may question whether the material which is better than gold in every test and hammering is really the same as actual gold, the passage nevertheless appears to assert the truth of alchemy. Another passage in the same work clearly represents the Alexandrian tradition. "All metals are transubstantiated into sun and moon which are equal in all respects to the natural materials in all operations, except that the iron of Alchemy is not attracted by the magnet and the gold of Alchemy does not gladden the heart of man, nor cure leprosy, and a wound festers which is made by means of it, a result which does not occur from natural gold. In all other operations, such as hammering and the test, it is like the natural material, and its color lasts forever."[18] The material which makes the festering wound is evidently brass or a similar alloy of base metals.

Arabic alchemy, and that of the later Europeans, contains other elements which were not derived from Alexandria. Professor R. Winderlich,[19] discussing the researches of Julius Ruska on the alchemy of al-Razi, says: "Alchemy as presented by al-Razi must have been preceded by a development that did not occur on Greek soil, for he uses substances, such as sal ammoniac, that were entirely unknown to the Greeks, and which for the most part bear Persian names. The logically thought-out theory of alchemy, firmly rooted in experiment, must have grown up in Persian soil." His evidence may indicate that alchemy came to the Arabs from Persia, but it certainly does not indicate that it originated in Persia. Perhaps it came to Persia from China.

The earliest alchemy with which we are acquainted is that which appeared in China in the third or fourth century B.C. It seems to have been of indigenous Chinese growth. The mystical philosophy of Taoism gave practical men a strong motive for wishing to prepare the pill of immortality. The dualistic Yin-Yang doctrine, which Liang[20] has shown did not prevail in the earliest Chinese thought but appeared full-grown at about the time that alchemy arose, evidently supplied a scientific background upon which alchemical theory and practice could flourish. The similarity of the Chinese doctrine to the doctrine of the "two contraries" which had existed at an earlier date in Egypt and in Mesopotamia suggests that the Chinese doctrine was an importation from one of these places.[21] It of course does not follow that alchemy was also an importation into China. While the doctrine of the "two contraries" led in the minds of the Alexandrians and later Europeans to a dualistic theory for the explanation of chemical phenomena, the same doctrine in the minds of the Chinese, who were not interested in chemical theory but were pursuing the practical end of preparing the pill of immortality, led to a theory of alchemy. Perfection of all kinds was to be procured by a proper balance of Yin and Yang. Wei Po-yang's process for the preparation of the pill of immortality, by the interaction of Yin and Yang in a closed container around which the fire, gentle at first and increased as the treatment advanced, was made to reverberate, is the same as that of the author of the "Speculum alchemiae," ascribed to Roger Bacon, for the preparation of the philosopher's stone from the sulfur and mercury principles.[22] There is no doubt of the general similarity between the methods and doctrines of the Chinese alchemists and those of the Muslims and later Europeans.

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[18] *Ibid.*, p. 495.

[19] *Jour. Chem. Education*, soon to be published.

[20] Ch'i-Ch'ao Liang, "On the Origin and Evolution of the Doctrines of Yin-Yang and Wu-hsing" (in Chinese), *Eastern Miscellany*, Shanghai, Vol. 20, No. 10, pp. 70–79, 1923. Discussed in SCIENTIFIC MONTHLY, 31: 225 *ff.*, 1930, and in *Isis*, 18: 216 *ff.*, 1932.

[21] For a fuller discussion of the extra-Chinese origin of Yin-Yang and of the distinction between chemical and alchemical theory, see the article on "The Dualistic Cosmogony of *Huai-nan-tzŭ* and its Relations to the Background of Chinese and of European Alchemy," *Isis*, soon to be published.

Since the Alexandrians had no alchemy, it is impossible that alchemy could have been imported into China from Egypt and unlikely that it was imported from Mesopotamia, where the dominant idea system was closely akin to that of Egypt and where, also, there is no evidence that alchemy was practiced. The possibility, however unlikely, is not excluded that alchemy may have been imported into China from India. At the same time the possibility remains open that Egyptian chemical knowledge and practices were imported into China, where the evident marvel of them led the Taoists to hope that they might supply means for the attainment of immortality. The similarity of the apparatus and reagents of the Alexandrian chemists and of the Chinese alchemists, the common interest in cinnabar and in mercury, are considerations which give plausibility to the speculation. Perhaps a knowledge of chemical behavior and of the equipment by which the behavior may be exhibited, controlled and applied came to China along with Yin-Yang from Egypt or Mesopotamia. But we must insist that the speculation applies to chemical knowledge and practice, not to chemical or alchemical theory. For the Chinese were not interested in chemical theory nor the Alexandrians in a theory of alchemy—and the dualistic chemical theory of the Alexandrians is later, perhaps several centuries later, than the dualistic alchemical theory of the Chinese. The similarities must be matched against the differences. The differences are evidences of a difference of origin for those portions of their respective doctrines and practices which differ from one another—and they appear to be precisely that the Chinese were pursuing the objectives of alchemy.

The Chinese alchemists were attempting to make real gold artificially, not because of its intrinsic value but because of its magical efficacy. They wished to procure longevity by eating food out of vessels which were made from it. They wished to compound from it edible pills of immortality by the eating of which they would be converted into *Hsien* or benevolent immortals. Such characteristically alchemical objectives were not pursued by the Alexandrians, who wanted the yellow imitation of gold because of its commercial value. The Chinese, wanting real gold for the compounding of the medicine, did not care whether the metal was of natural origin or resulted from the processes of alchemy: the two were identical. The notion that the noble metal itself was the material of the elixir seems to have survived in the motive which impelled the Arabs and medieval Latins to prepare an elixir of potable gold, but the later alchemists hoped only to procure longevity from it. Mohammedanism and Christianity promised them an immortality anyway. The notion of *Hsien* does not appear in European alchemy at all. But the extraordinary powers of the *jinni* of the Arabian Nights are so like those of the *Hsien* that we wonder whether the Arabic word *jinn* may not be derived from the Chinese *Hsien*.

Some of the dominant characteristics of Chinese alchemy are made clear by the following remarkable passages from Ko Hung's chapter on the Yellow and the White (trans. Wu), written about 317–332 A.D.

> It is another story with the *Chên Jen* (Men of Truth, Men Proficient in the Art, Sages). For they make gold with the purpose, not of getting rich, but of becoming *Hsien* by eating it. Therefore it is written in the Book, "Gold can be made wherewith people can be raised above this worldly life." Silver may be eaten for similar ends but is not as effective as gold.

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[22] Discussed in the place last cited.

Then I asked further, "Why should we not eat the gold and silver which are already in existence instead of taking the trouble to make them? What are made will not be real gold and silver but just make-believes."

Said Chêng Chün in reply, "The gold and silver which are found in the world are suitable for the purpose. But *Tao-shih* (Seekers of the Way) are all poor; witness the adage that *Hsien* are never stout and *Tao-shih* never rich. *Tao-shih* usually go in groups of five or ten, counting the teacher and his disciples. Poor as they are, how can they be expected to get the necessary gold and silver? Furthermore, they can not cover the great distances to gather the gold and silver which occur in nature. The only thing left for them to do is to make the metals themselves.

"In that they are the essences of the medicines, the gold and silver made are superior to those found in nature. . . .

"The gold obtained by successful compounding is uniform inside and out. It may be put through a hundred workings without suffering any change. Therefore it is written in the formulas for its making that it may be made into nails. That shows its strength. Such results come of responsive infusion of the *Tao* (Way) of nature. Why should such deeds be called make-believes?

"Make-believes should be like the besmearing of iron with *Tsêng Ch'ing* (a blue compound of copper?) whereby the metal takes on a reddish sheen simulating copper, and the action of egg-white on silver to obtain a yellow coloring resembling gold. In all these cases there are merely external changes but no internal transmutations.

"The fungus *Chih* (Plant of Longevity) is a natural growth. But according to the *Hsien Ching* (Book of Immortals) it may be cultivated by means of the five stones and the five plants. The resulting plant will be exactly like that found in nature in the power of giving long life when eaten. The case is similar to the making of gold."[23]

The Chinese alchemist was well aware that there are chemical means by which the appearance of the metals may be changed, but insisted that the changes are merely superficial and are different from the real transmutations which he wanted and believed to be possible. We are not acquainted with anything like this in the writings of the Alexandrians and Byzantines.

Chinese alchemy and Alexandrian chemistry are alike in being erected upon a nature theory of the "two contraries," and alike very largely in the materials and apparatus with which they worked. They are utterly different in their objectives. It is probable that the dualistic philosophy came to China from Egypt or Mesopotamia, and it is possible that a considerable amount of chemical knowledge came with it. Alchemy evidently originated in China among the Taoists, who hoped by means of it to gain an immortality which their religion did not promise them. The evidence indicates that it came to Europe from China, presumably across Persia to the Arabs among whom the Chinese alchemical tradition mingled with the Alexandrian chemical one to form a body of doctrine which was transmitted to the Latins. In Latin alchemy, moreover, evidences of the two traditions are distinctly discernible.

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[23] "An Ancient Chinese Alchemical Classic, Ko Hung on the Gold Medicine and on the Yellow and the White, the Fourth and Sixteenth Chapters of Pao-p'u-tzŭ translated from the Chinese by Lu-Ch'iang Wu with an Introduction, etc., by Tenney L. Davis," *Proc. Amer. Acad. Arts and Sciences*, 70: 221–284, 1935. Quoted passage, pp. 260–261.

THE WORLD'S FOOD AND THE ARGENTINE BIRTH RATE

By Dr. SIMON G. HANSON

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In 1923 Professor Edward M. East, discussing the world's food supply, suggested that the River Plate area would be "the last great temperate expanse of arable land to become sufficiently populous to forbid food exportation without a return in kind."[1] He believed that population increase in Argentina had not yet reached the point of maximum acceleration, assuming a continuance of free immigration, stable government and dominance of the Catholic faith. To-day Argentina is agitated over a declining birth rate, that has fallen with disturbing rapidity and regularity since 1923. Far from accepting this tendency as a factor that will lengthen its period as a supplier of food to international markets, many influential Argentine authorities are urging the adoption of a policy of stimulating immigration and redirecting the flow of migratory people to its ports so as to hasten the day when the home market will challenge the country's capacity to produce foodstuffs. This view is in such sharp contrast with informed opinion of the immediate pre-war period that it is interesting to note the underlying factors.

For some time previous to the outbreak of the world war Argentine economists had been viewing the heavy volume of immigration with considerable concern. The belief was gaining ground that the traditional policy of unrestricted non-selective entry had outlived its usefulness. During the period 1905–1913 immigration averaged 163,447 persons per year, compared with 47,788 in 1892–1904 and 51,864 in 1870–1891. Of even more significance than the volume was the fact that about 70 per cent. of the immigrants were male, over 65 per cent. unmarried, and over 50 per cent. between the ages of 21 and 40; children under 13 made up only 14 per cent. of the newcomers and persons over 60 less than 1 per cent. The large proportion of young able-bodied immigrants coupled with abundant economic opportunities to produce a very high birth rate. In the period 1910–1914 the annual birth rate was 37.86 per thousand; the natural increase of 20.78 during this time had few parallels among important nations. Foerster has demonstrated that the Italians who formed the largest single element in the new population were more prolific in Argentina than in Italy, and it is probable that the birth rate among foreign-born generally was higher than that of native Argentines.

Although the process of assimilation was facilitated by the preponderance of Latins, nevertheless it became increasingly difficult to absorb the immigrants economically; industrial adjustments were slow and in the meantime a problem in unemployment threatened. There was fear, too, lest national racial characteristics be submerged by the flood of foreigners. By June, 1914, the population included 5,100,000 native-born persons of European descent, 400,000 native-born with traces of Indian or Negro blood, and 2,300,000 foreign-born almost wholly European. Since the native population included women and children, while the foreign element was composed mainly of adults, the significance of these proportions is readily apparent.

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[1] E. M. East, "Mankind at the Crossroads," p. 86. New York, 1923.

It is not surprising, thus, that a movement to make immigration more selective arose. However, the war intervened to reverse the currents of migration. There was a net outflow of 214,175 persons in the six years 1914–1919. Thereafter Argentina regained its powers of attraction, and the flow of immigrants slowly advanced towards pre-war proportions. From 1920 to 1930 the net immigration was about 80,000 persons annually. But important changes occurred in the character of the inflow. The proportion of non-Latins increased from less than 15 per cent. to over one fourth of the total, and there was a slightly larger married group (30 per cent. in 1901–1910 and 40 per cent. in 1920–30).

The depression brought a number of new influences to bear on the Argentine economy. The prevailing spirit of nationalism and the general effort to attain self-sufficiency abroad cut down the markets for Argentine foodstuffs and reduced its purchasing power; the stream of immigration was once more shut off and in the four years 1931–1934 there was a net outflow of about 20,000 persons. This movement was especially important, because the emigrants were for the most part men of races easily assimilated, having trades or professions and of productive ages, while the recent immigrants are increasingly of less adaptable nationalities, such as Poles, Lithuanians, etc. Its markets reduced, Argentina too adopted the nationalistic philosophy. Great advances were made in the diversification of industry by the large-scale development of hitherto neglected crops, such as cotton and fruit, and by the growth of manufacturing. Economists began to make studies of the population needed to absorb the current industrial output and sought to learn what growth might be expected from the natural increase in population.

Little comfort was derived from the birth rate, however. It has fallen every year since 1923; the rate in 1934 was 25.0 per thousand, compared with 33.97 in 1923. The accompanying decline in the death rate from 14.79 to 11.50 was not sufficient to prevent a reduction in the natural rate of increase from 19.18 to 13.50. Since the tendency is for the urban population to gain at the expense of the rural (the percentage of population living in towns and cities of 2,000 population or over being 37.4 per cent. in 1895, 53 per cent. in 1914 and estimated at 60 per cent. in 1934), it is equally disturbing to find that the birth rate has declined even faster and to a lower level in the federal capital, which contains about one fifth of the total population. The birth rate in the federal capital fell from 34.09 in 1914 to 24.94 in 1924 and 18.12 in 1934. While the annual rate of increase of Argentine population was 3 per cent. in the period 1921–1925 it was only 1.4 per cent. in 1934.

Several factors have contributed to the decline in the birth rate. The decreasing influence of immigration is one. The absence of influential religious command is another, since the church is less powerful here than in certain other Catholic countries of Latin

TABLE I

GROWTH OF THE ARGENTINE POPULATION
(Rates per thousand inhabitants)

Year	Birth rate	Death rate	Natural increase
1915–19	33.94	17.12	16.82
1920	32.27	15.47	16.80
1921	32.75	15.78	16.97
1922	33.10	14.03	19.07
1923	33.97	14.79	19.18
1924	32.76	14.32	18.44
1925	31.76	14.11	17.65
1926	31.24	13.63	17.61
1927	30 78	14.11	16.67
1928	30 76	13.21	17.55
1929	30.24	13.83	16.41
1930	29 48	12.67	16.81
1931	28.50	13.38	15.12
1932	27.03	11.94	15.09
1933	25.90	11.61	14.29
1934	25.00	11.50	13.50

America. Military pressure such as puts a premium on the breeding of large families in some European countries is absent, too. In evaluating the economic factor it should be remembered that the unemployment problem in Argentina was relatively unimportant during the depression. Alejandro E. Bunge, the famous Argentine statistician and economist, accounts for this by three reasons. First, the fact that Argentina was under-built and badly in need of construction. Secondly, the diversification of industry; in 1933 the percentage of employed population in commerce, industry and agriculture-grazing was 12.1 per cent., 43 per cent. and 22.6 per cent., respectively, compared with 10.8 per cent., 38.5 per cent. and 27.2 per cent. in 1914; and this tendency continued in 1934 and 1935. Thirdly, the volume of exports of foodstuffs and raw materials was well maintained; export tonnage in the five years 1925–1929 totaled 75,041,000 tons, compared with 74,359,000 tons in 1930–1934.

TABLE II

RATE OF ANNUAL INCREASE IN POPULATION

Year	Rate
1915–19	1.37 per cent.
1920	2.19 " "
1921	2.50 " "
1922	3.11 " "
1923	3.71 " "
1924	3.09 " "
1925	2.59 " "
1926	2.70 " "
1927	2.77 " "
1928	2.59 " "
1929	2.50 " "
1930	2.37 " "
1931	1.79 " "
1932	1.66 " "
1933	1.49 " "
1934	1.40 " "

It is clear that those who hope to reduce Argentina's dependence on foreign markets must be prepared to wait a long time if they count only on the vegetative population increase to expand the home market. The government is therefore being urged from many quarters to encourage immigration as one point in a general plan to organize a sounder national economy. Economic capacity to absorb a million immigrants, the argument runs, could be created by providing opportunities to purchase land, by organized colonization and by a break-up of the large estates; past efforts to effect such a reorganization of land ownership have amply demonstrated the difficulties. The further diversification of industry is also being sought. In addition, it is argued that the racial capacity to absorb such a large foreign element has changed vastly since 1914. Dr. Bunge estimates that in June, 1935, the composition of the population was as follows: native-born of European descent, 9,480,000; native-born with traces of Indian or Negro blood, 300,000; foreign-born, 2,500,000. In other words, while in 1914 the native population was little more than double the foreign, it is to-day about four times as numerous.

The rate of natural increase of the Argentine population still exceeds that of other leading nations on the continent, of nations formerly supplying man-power to the River Plate and of the great grain-export competitors. For instance, the rates in 1931–32 compared as follows: Argentina 16, Chile 11.4, Italy 9.4, Canada 12.5, Australia 8.3. But there is no denying that unless public opinion forces the government to take the strenuous measures that will be necessary for attracting immigrants on a large scale, the declining birth rate has definitely extended the period during which Argentina may be relied upon to furnish food for over-populated areas.

CONSERVATION AMONG PRIMITIVE HUNTING PEOPLES

By **WILLIAM CHRISTIE MACLEOD**
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THE hunting and gathering of primitive non-agricultural peoples was not a hit-or-miss random search for plant and animal food and industrial materials.

Dependent upon naturally limited resources in a limited territory for themselves and their descendants, they took stock of their limited resources. They knew in detail just what the supply of each thing was—wild grasses, berries, roots, animals, trees—and knew where each was to be found when wanted and in approximately what quantity. Thus, for the Australian aborigines of North Queensland Roth wrote:

> Independently of the greater or less extent of country over which the community as a whole has the right to hunt or roam . . . there are definite territorial divisions, certain tracts of country for each family, each such tract bearing a distinctive name. In the same way that a European knows what vegetables, shrubs, or flowers are growing in his garden, so do the natives have a fair idea of the amount of any special growth of edible fruits, seeds, or roots, as well as the particular haunts of the various animals and birds found in their particular piece of ground.[1]

And of the northeastern Algonkian Indians and their family hunting territories Speck writes.

> Economically these territories were regulated in a very wise and interesting manner. The game was kept account of very closely, so that the proprietors knew about how abundant each kind of animal was, and hence could regulate the killing so as not to deplete the stock."[2]

A hunter can "tell at any time the number of animals which he can dispose of each year in the district without endangering the supply.[3]

The pressure of population upon resources made for intensive exploitation of the limited stock of resources. Of the Hopi, for example, we are told that "there is almost no plant which the Hopi does not use in some way," and "every berry patch for miles around is known and visited" Our increasing number of exhaustive volumes on primitive ethnobotanies affords wide-spread examples of such intensive use of wild resources. Of the Hupa ethnobotany, for example, we read that "They seem to have discovered and made use of every vegetable fit for food, and in two instances have learned to render poisonous plants harmless."[4]

Out of such a background of natural limitation of supply, pressure of population on the limited supply, a thorough inventory and intensive exploitation, one might expect that purely economic motives might lead to a conservation of those elements of the supply which experience would show would diminish and tend to disappear if conservation were not applied. However, some of the facts available on the subject suggest that spiritual motives may have played a large part in giving rise to conservation. To primitive man there is soul in all things animate and (to us) inanimate.

The primitive hunting Yukaghir of northeastern Siberia, for example, in hunting the wild reindeer always took care to leave some of a herd for breeding; and in closing a stream with a cross weir part of the fish were always allowed to pass first that they might spawn. Wasteful killing of animals was taboo. They appear to have rationalized their rude conservation in spiritual terms, however. To explain why the elk disappeared from a certain region they tell a tale which explains that the spirit of the elk disapproved of a case of wasteful killing of elk.[5] An almost identical tale is told by the Micmac Indians of an island off Nova Scotia to explain the disappearance of the moose from their particular area. After an improvident killing of moose the remaining moose, offended, left the island, never to return.[6] The Kwakiutl Indians of Vancouver Island,[7] in peeling bark from cedar trees for the various important industrial uses to which this bark was put, never stripped off all the bark of a tree, "because the young cedar tree would die and then another cedar tree nearby would curse the bark peeler so that he also would die." And the taking of any bark at all from a tree must be propitiated. The bark peeler stands before the tree, uttering humble apologies and explaining the necessity of taking some bark.

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[1] W. E. Roth, North Queensland Ethnography Bulletins, No. 8, p 8, Brisbane, 1900.

[2] F. G. Speck, Memoir 70, Canadian Geological Survey, p. 5, Ottawa, 1915.

[3] F. G. Speck, *Old Penn Weekly*, p. 185, University of Pennsylvania, 1914-15.

[4] W. Hough, *American Anthropologist*, 1897.

Speaking of the Ojibway, a literate Ojibway himself writes:

> In addition to the belief in the immortality of their own souls, they suppose that all animals, fish, trees, stones, etc., are endued with immortal spirits and that they possess supernatural power to punish any one who may dare despise or make any unnecessary waste of them. . . . In their heathen state they very seldom cut down green or living trees, from the idea that it puts them to pain; and some of their powwows have pretended to hear the wailing of the forest trees when suffering under the hatchet or axe.[8]

But whether or not in its origins conservation was of spiritual motivation among some or all peoples who have practiced it, or whether the spiritual attribution is a mere rationalization or adventitious association with the practice, nevertheless, once instituted, conservation becomes an economic practice and the tribal technology is adjusted to it; it becomes one aspect of their "state of the arts" which could not be discontinued without a diminution in food and other supplies. And it is a fact that our more important references to conservation among primitives do not carry any reference to anything involved except economic expediency. These references we shall now turn to.

Among the Choctaw of the southeastern United States in their old home in Mississippi, for hunting, the tribe broke up into families and left the village to go off into the woods for the regular hunting seasons. Laws were enacted first, "governing the amount of game that might be killed by each family on the five rivers, and how much by the whole band or okla." Every month each band chief was required to report to the head chief just how much had been killed by each family under his control. Besides conservational regulation of quantity there were laws confining hunting of one type of game and another to proper seasons and in proper places, laws even controlling fish poisoning and spearing.[9]

Among the Mahickan much farther north:

> It was a law among them not to kill any more game than was necessary for their own use, none even to barter, which might have produced a temptation to waste their animals. By these regulations their game was preserved undiminished, the consumption being no greater than the natural increase. This law continued in force until the Chuckkathuk or white people came to this island.[10]

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[5] W. Jochelson, Jesup Expedition, Memoirs of the American Museum of Natural History, Vol. 10, pp. 146, 148, 150, 1910.

[6] F. G. Speck, Beothuk and Micmac, Indian Notes of the Heye Museum of the American Indian, p. 115, 1922. For general considerations see F. G. Speck, "Naskapi" (Chapter 5 on "Animals in Special Relation to Man"), 1934.

[7] F. Boas, 35th Annual Report of the Bureau of American Ethnology, 1913–14, pp. 616–619. In the Documentos Ineditos . . . Espana, Vol. 104 pp. 159–60 (Manual de Jacinto de la Serna) is a similar Aztec prayer assimilated to Catholic ritual.

[8] P. Jones, "History of the Ojibway," p. 104, 1861.

[9] J. R. Swanton, "The Choctaw," *Bulletin* 103, Bureau of American Ethnology, pp. 54, 101, 1932.

[10] A. Skinner, "Mahickan Ethnology," Milwaukee Museum Publications, Vol. 2, 1925 (from a Manuscript of 1822).

Among the still more northern hunting Algonkians what amounts almost to game farming appears, evidenced in the accounts of Speck, Davidson, Hallowell and Cooper among the various bands. The native owner of a family hunting tract explains:

> The beaver is the Indian's pork; the moose, his beef; the partridge, his chickens; the caribou or red deer, his mutton. All these formed the stock of his hunting ground, which would be parcelled out among his sons when the owner died. He would say to each of his sons: "You take this part; take care of this tract; see that it always produces enough."

Beaver was made the object of the most careful "farming"; the numbers of occupants, old and young, to each "cabin" of the animals was kept account of; breeders were not killed; each year only young or very old animals were slain. In certain districts moose or caribou would be protected during one year; in other districts during the next year. Some proprietary families went so far as to divide their own territories up into quarters around a center, "hunting in a different quarter each year and leaving the tract in the center as a reserve to be hunted over only in case of shortage from the exploited tract." [11]

A conservation practice which might conceivably have led on to the development of agriculture was observed by Curtis among the Kwakiutl of northern Vancouver Island.[12] Among them, clover beds, like other lands, are held within families, and were particularly valuable because clover roots were a high-priced luxury, being considered indispensable to good health. "For this reason the land is well cared for. The main root stocks are never taken, and such pieces as are not deemed good for food are put back into the ground. This is the nearest the Kwakiutl ever approached to agriculture."

The supply of firewood was vitally important to the Indians. Consuming all the wood so available within a practicable distance of a settlement would necessitate moving the settlement with resultant great disadvantage; this was as much a cause of village removals as was weed infestation of farms among the agricultural tribes. One note of conservation is available with reference to firewood and to bark and wood used industrially in an area where such would be particularly important. An Anvik, Alaska, Indian told an ethnologist that "in getting wood or brush from the forest we do not take all there is in any one place. We depend on the wood or bark. If we destroyed it, we would become vagabonds." [13]

That conservation is aboriginal, prior to European influence, where we find it, might be brought in question, but there seems to be no doubt of its aboriginality. The Choctaw and Mahickan data I have already cited are for the pre-White period, though reported later. And Cooper[14] found among the James Bay Cree that white influence was breaking down the native conservation. Speck[15] in his Mistassini investigation affords evidence that the practice antedated the coming of the fur-trading companies to the northern woodlands and tundras.

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[11] Speck, Memoir 70, Canadian Geological Survey, p. 189, Ottawa, 1915, and *Old Penn Weekly*, p. 5, University of Pennsylvania, 1914–15. See also his "Lake St. John Family Hunting Territories," *Anthropos*, 1927; "Mistassini Family Hunting Territories," *American Anthropologist*, 1923; and "Oka Family Hunting Territories," *Ibid.*, 1926. Also the data on conservation in D. S. Davidson, "Waswanipi Family Hunting Territories, Indian Notes, Heye Museum, N. Y, 1928; and "Notes on Tête de Boule," *American Anthropologist*, 1928.

[12] E. S. Curtis, "The Kwakiutl, p. 43, 1910.

[13] E. C. Parsons, "The Dene of Anvik," *Anthropos*, p. 68, 1920; *Cf.* W. C. MacLeod, "Fuel and Early Society," *American Anthropologist*, 1925.

[14] J. Cooper, "James Bay Cree," *American Anthropologist*, 1930.

[15] F. G. Speck, Memoir 70, Canadian Geological Survey, p. 459, Ottawa, 1915.

Dunn in 1842 would seem to imply that the northern woodlands Indians were taught conservation by the fur companies;[16] but Harmon was in the same western country many years before Dunn.[17] He was the first white man among the Carrier Indians of the western plateau, and found conservation there among them, quite without the possibility of fur company influence. Incidentally, he also found private or family ownership of hunting lands, another thing general among the hunting peoples of North America which some skeptics have thought might be a result of white influence. The fact is that the natives of the northwestern woodlands had sometimes to struggle against the breakdown of their conservation system from some fur-trading influences. About 1811 "free hunters," including a band of Iroquois detached by the fur trade, entered the northwest country and killed beaver recklessly. As a result they incurred the hatred of the Piegan, Cree and other natives of the region because of the diminution of the numbers of beaver.[18] Back in their own country over a century and a half earlier the Iroquois, however, were conservationists, as evidenced by their statement of the cause of the war between them and the Eries. La Hontan writes that the Iroquois made war on and exterminated the Eries because they had trespassed on Iroquois territory and "had acted contrary to the customs of all Indians, for they had left none of the beavers alive; they killed both males and female."[19] The Eries were exterminated in the 1630's, a time when the fur trade was just having its effect in this area.

SOME POSSIBILITIES IN THE DATA

The above appears to be all that is available on conservation among primitive hunting peoples, but the absence of other note of it may mean merely that the subject has not been inquired into in the field. If and when new data are available it may be possible to reach some interesting conclusions concerning the place of conservation in the economic development of primitives. In conclusion, we may mention just two of the possibilities.

Meeting with the data, orginally, it struck me that the functional relationship between land tenure and conservation would appear to indicate that family or private ownership of hunting lands (and such is universal among pre-agricultural hunters) was a necessary prerequisite of conservation. But upon discovering the Choctaw data, this seems ruled out, for we have no evidence that the Choctaw, who were agriculturists, too, although hunting was important among them and they were sellers of meat to other agricultural tribes, had family division of the hunting grounds. The Choctaw facts indicate that tribal political control could effect conservation without private ownership and management.

It occurred to me, also, that conservation practice may have been the practice which led to the development of domestication of plants and of animals. Aside from the dog (kept originally as a pet, perhaps) the reindeer appears to have been the first animal domesticated by man, and this occurred in sub-boreal Asia.[20] Since our data on conservation is largely for the adjacent sub-boreal hunting cultures of North America, perhaps one may consider it possible that a conservation technique played its part in the original reindeer domestication whatever part the keeping of pets or

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[16] J. Dunn, "History of Oregon," p. 65, 1842.

[17] D. W. Harmon, "Journal," (1810–19).

[18] Dunn, p. 65, and D. Thompson, "Narrative," (1784–1812), Champlain Society Publications, pp. 205–6, 553, 1916.

[19] La Hontan, "Voyages" (1682–1703), 2 vols.; 2nd ed., 1725; Reprint Vol. 2, p. 62, 1922.

[20] According to the well-considered investigations of Flor and Koppers of Vienna.

animals for sacrifice may have played in other domestications. However, as for plant domestication, my own study of the motivations underlying certain important plant domestications leads me to doubt that any plant domestication ever evolved from an extension of the conservation technique.

UNITED STATES AND BRITISH UNITS OF WEIGHTS AND MEASURES[1]

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THE weights and measures units in commercial, industrial and ordinary every-day use in the United States are often referred to as the English or customary units, as distinguished from metric units, and they are generally assumed to be the same as the corresponding units in use in Great Britain. While in general this assumption is correct, there are a few important exceptions.

The U. S. yard and the British yard, while differing slightly in basic definition, are essentially equal for all practical purposes except the most precise linear measurements. The various multiples and subdivisions of the yard are also essentially equal. Similarly, the U. S. avoirdupois pound and the British Imperial pound are substantially equal, although differing slightly in basic definition. On the other hand, the U. S. bushel, gallon, quart and fluid ounce are quite different from the British units of the same names. Of these, the units of volume, as applied to liquids, are perhaps most often confused.

The U. S. gallon is defined as a volume of 231 cubic inches; the U. S. liquid quart as 1/4 U S. gallon, or 57.75 cubic inches; and the U. S fluid ounce as 1/32 U. S. liquid quart, 1/128 U. S. gallon or 0.2256 cu. in.

The British (Imperial) gallon is defined as the volume of 10 pounds of water, under specified standard conditions of temperature and pressure. It is equivalent to 277.420 cubic inches. Thus the British gallon is larger than the U. S. gallon by slightly more than 20 per cent.

The situation with reference to the measurement of volume of liquids, in terms of U. S. and British units, is further complicated by the fact that the relation between the gallons does not hold for certain subdivisions of the gallons. For example, while both gallons are subdivided into quarts, fluid ounces and drams, the method of subdivision is not the same in all cases, and while the same relation holds between the quarts as between the gallons, it does not hold between the fluid ounces or between the drams. This arises from the fact that while in each system of units 4 quarts make 1 gallon, and 8 drams make 1 fluid ounce, the quarts are not divided into fluid ounces in the same way. In the U. S. system the quart is divided into 32 fluid ounces, while in the British system the quart is divided into 40 fluid ounces. The relations of the units of the two systems, arranged in tabular form, are as follows:

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[1] Published by permission of the director of the National Bureau of Standards.

U. S. System

8 fluid drams = 1 fluid ounce
32 fluid ounces = 1 quart (liq.)
4 qts. = 128 fl. oz = 1 gal =
231 cu. in. = 8⅓ lb.
of water (approx)

British (Imperial) System

8 fluid drams = 1 fluid ounce
40 fluid ounces = 1 quart
4 qts. = 160 fl. oz. = 1 gal =
277 420 cu. in. = 10 lb.
of water at 62° F

From the relation shown in the above table it is found that while the British gallon and quart are larger than the corresponding units of the U. S. system, the British fluid ounce and dram are smaller than the corresponding units of the U. S. system.

The relations[2] are:

1 British (Imperial) gallon	= 277 420 cu in
	= 1.20095 U S gallon
1 British (Imperial) quart	= ¼ gallon (Imperial)
	= 69 355 cu in
	= 1 20095 U S liq quart
1 British (Imperial) fluid ounce	= 1/40 Imperial quart
	= 1 7339 cu in
	= 0 9608 U. S. fluid oz
1 British (Imperial) fluid dram	= ⅛ Imperial fluid oz
	= 0 2167 cu in
	= 0 9608 U S. fluid dram
1 U S gallon	= 231 cu in
	= 0 83267 Imperial gal
1 U S quart (liq)	= ¼ U S gallon
	= 57.75 cu in.
	= 0 83267 Imperial quart
1 U. S. fluid ounce	= 1/32 U S quart (liquid)
	= 1 8047 cu. in
	= 1 0408 Imperial fl. oz
1 U. S fluid dram	= ⅛ U S fluid ounce
	= 0.2256 cu in
	1 0408 British fluid dram

The difference between U. S. and British units of the same name, as shown in the above table, sometimes leads to uncertainty and confusion in the measurement of volumes of liquids and in the interpretation of markings on containers of liquid commodities. The situation is particularly troublesome in the case of products bottled and labeled in one country and subsequently shipped into and sold in another country; as, for example, in transactions between residents of the United States and Canada.

It is reported that an American motorist, on her return from Canada, remarked that she had found Canadian motor fuel superior to the U. S. product as regards miles per gallon. Had she carried her observations further she would have learned, no doubt, that in Canada her tank did not hold as many gallons as she was accustomed to putting in it at home and that she paid more per gallon in Canada than at home.

Sellers of imported bottled products are not always above suspicion in the matter of interpretation of markings, and newspaper advertisements of such products as wines and liquors are sometimes misleading. For example, a Washington newspaper not long ago carried an advertisement in which certain Canadian products were listed as "Canadian quarts," "full Canadian quarts" and "Imperial quarts." As a matter of fact there is, of course, no such unit as a "Canadian quart" or a "full Canadian quart," as distinguished from the British or Imperial quart. The bottles advertised were, in all probability, short measure "fifths," full measure "fifths" and Imperial quarts, respectively (a "fifth" being 1/5 gallon).

A point already mentioned that should be kept in mind, in relation to U. S. and Canadian liquid measures, is that the Canadian, British or Imperial fluid ounce, instead of being 20 per cent. larger than the U. S. fluid ounce, as is the case with the gallon and quart, is about 4 per cent. smaller than the U. S. unit of the same name. That is, in order to be equivalent, Canadian and U. S. prices per quart and per gallon should be in the ratio of 120 to 100; and prices per fluid ounce should be in the ratio of 96 to 100.

Let us turn now to the British and U.

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[2] The relations given herein are correct to the decimal places given; they should not, however, be taken as exact.

S. bushels. The British bushel is defined as 8 Imperial gallons, which is equivalent to 2219.36 cubic inches, and the U. S. bushel is defined as 2150.42 cubic inches. That is, the British bushel is larger than the U. S. unit of the same name by about 3.2 per cent. The British bushel is divided into 32 quarts of 69.355 cubic inches, while the U. S. bushel is divided into 32 dry quarts of 67.20 cubic inches. Thus the British (Imperial) quart, which is used for both liquid and dry commodities, is larger than the U. S. dry quart by 3.2 per cent., while it is larger than the U. S. liquid quart by 20.1 per cent.

Now just a word about pounds and tons. As already stated, the British and U. S. avoirdupois pounds are practically equal; but in the United States 100 pounds make 1 hundredweight, while in Great Britain the hundredweight is 112 pounds or 8 "stone" of 14 pounds. Similarly, the ton in the United States is usually 20 hundredweight, or 2,000 pounds, while in Great Britain it is 20 hundredweight of 112 pounds each or 2,240 pounds. (The "long ton" of 2,240 pounds is used to some extent in the United States, especially in the coal industry, while the "cental" of 100 pounds is used to some extent in Great Britain.)

It is seen from the foregoing that although our customary weights and measures units are in many cases the same as the British units of the same name, they differ rather widely in certain other important cases.

PLANKTON AND INVERTEBRATES OF THE ANTARCTIC

By DR. EARLE B. PERKINS

ZOOLOGICAL LABORATORY, RUTGERS UNIVERSITY; ZOOLOGIST, BYRD ANTARCTIC EXPEDITION II, 1933–1935

WHEN the second Byrd Antarctic Expedition left Boston on October 11, 1933, for extensive explorations and scientific investigations in the Ross Sea Dependency and Marie Byrd Land, the biological staff had outlined a rather elaborate program. This included work on bacteria, plankton, such invertebrates as were likely to be met with, the relatively few fishes and the penguins and seals which are so typically Antarctic. Further, a collection of algae, lichens, mosses and microscopic life in the fresh water pools was to be made by the sledging parties going to the mountains, and the skins of birds and seals procured for study and museum display. In addition to bringing back preserved specimens it was the hope of Admiral Byrd and the biologists that live seals and penguins could be brought to the States for further study of their physiology and behavior.

It is gratifying to find in summarizing the accomplishments of the expedition that a great deal of the original program has been carried out. This is particularly noteworthy in view of the many difficulties which were encountered in a region so remote and where unfavorable weather conditions and environmental handicaps greatly impeded activities. Studies and collections were made in every phase of the biological work as outlined in the beginning, and when finally presented in the published reports and as museum specimens will amply justify the inclusion of a biological program in the work of a polar expedition.

This preliminary account of studies on invertebrate life and the composite plankton represents only that part of the program with which I was primarily concerned, the other phases of the investigations being presented separately by those members of the staff responsible for them.

PLANKTON

This includes the zoo- and phytoplankton collected and photographed during the two crossings of the Pacific, within the Antarctic Circle, the Ross Sea and the Bay of Whales. Collections began shortly after leaving Panama and were carried on with but few interruptions to Easter Island, and then followed a great circle course to Wellington, New Zealand. This was over a route infrequently traveled. Within the Antarctic Circle the ship pushed eastward through unknown waters to the 118th meridian. Collections were made in this interesting area of icebergs and pack ice where no ship had been before, as well as over the return course to the Ross Sea.

At Little America there was little opportunity for extensive collections because of unfavorable weather conditions and heavy ice. Several hauls were made, however, through the bay ice during the period of darkness, as well as rich collections from upturned blocks of ice which were deeply colored with many species of diatoms. As soon as ice conditions permitted, in December, 1934, vertical hauls were made with the plankton net through cracks in the bay ice at as frequent intervals as weather conditions permitted. This was continued until the arrival of the ships late in January, 1935, when the work was carried on aboard the S.S. *Bear of Oakland* in the Ross Sea, and on the passage to Dunedin. From there a continuous series of samples was taken aboard the S.S. *Jacob Ruppert* at 50-mile intervals across the southern Pacific to Panama, via Easter Island, by allowing a stream of sea water from the main circulating pump to run through the net. In all cases records were kept of temperatures and salinities, and a complete photomicrographic record made of the many species obtained—the photographs being made before the preservative had altered the appearance of the specimens. In some cases where the material warranted it, cinemicrographs were made of active specimens. This was of particular interest in connection with living rotifers, tardigrades and protozoans brought back from the Edsel Ford Mountains in Marie Byrd Land and from the Rockefeller Mountains.

Pending the completion of the task of identifying the many species found in the plankton very little can or should be said concerning them, other than to state the character of the hauls in a general way. The following is a brief review of the nature of the plankton samples in the wide range of areas covered.

South Pacific, November–December, 1933. The vast majority of organisms obtained consisted of many species of copepods with striking variety as to size, shape and color. Also making up a large part of the catches were diatoms, dinoflagellates, radiolarians, heliozoans, colonial hydroids, Sagittae, a few annelids, pteropods and other small gastropods, including a pelagic nudibranch. During the afternoon of December 1, in Latitude 38° 30′ South—Longitude 169° 45′ West, large brown patches were seen in the water for the first time, varying in size from a foot or two square to about 25 by 200 feet, all with sharply defined edges. Plankton samples taken during this time contained vast numbers of Peridinium, not hitherto seen.

Between November 21 and November 29 only two samples were retained because of the nearly complete absence of plankton in the filtered water. This was along the 33rd parallel between 122° and 161° west longitude in a zone of rapid change of water temperature. On November 20 the water temperature was

19.2° C. and on November 29 it had dropped to 16° C. At this colder temperature and beyond the transition zone the plankton became abundant again.

On the whole, the amount and variety of life in the samples taken, considering the great volume of water filtered, is relatively small compared to the planktonic "soup" so easily obtained in colder waters. Nevertheless, the collections are of considerable interest because they were made in a region far removed from the usual paths of ships across the Pacific.

Antarctic Seas. With rapidly falling water temperatures on the voyage to the Ross Sea from New Zealand, there was the expected change in the character and abundance of plankton. Whereas copepods and other small crustaceans had been the most conspicuous feature of warmer waters, with temperatures lowering rapidly from 10° C. out of New Zealand to – 1.5° C. in the pack ice, the algae became dominant to the eventual exclusion of all other forms of life at the surface. Myriads of these organisms were caught at each haul of the net, representing many different species. Pack ice and the water line of bergs and ice islands were conspicuously stained a yellowish-green by the countless numbers of these unicellular plants.

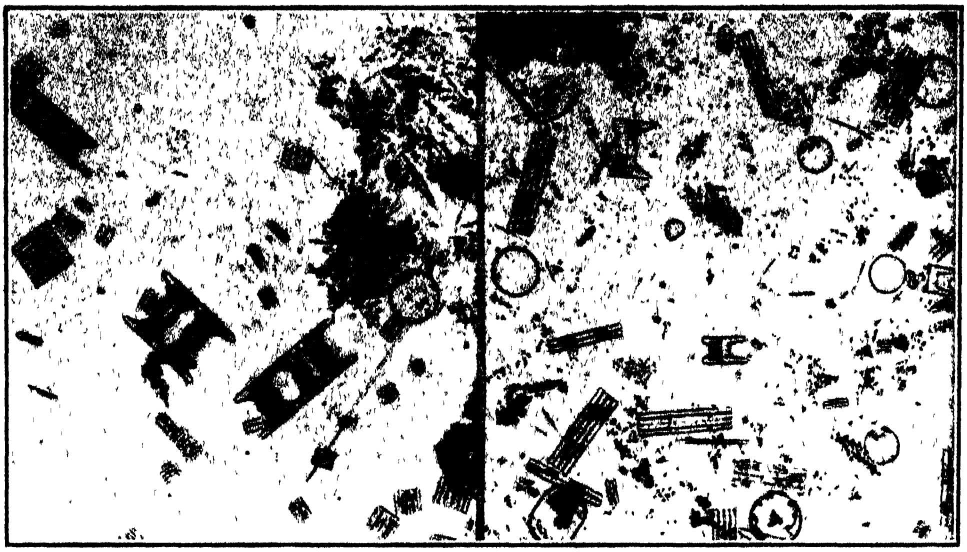
Bay of Whales. After construction of the laboratory at Little America and the major part of establishing the winter camp had been completed, work was resumed on the plankton of the Bay of Whales. The first successful haul was made on April 9, 1934. The newly formed bay ice was then about two feet thick. A vertical haul of 300 feet yielded an abundance of copepods and a few diatoms. There were also several specimens of living globigerina and radiolaria. A block of ice from the bottom layer of the newly formed bay ice contained several types of diatoms which had become trapped as the water froze. At the same time a piece of plankton-colored ice from an upturned piece of pressure ridge was brought back to the laboratory and found to contain a highly concentrated mass of phytoplankton.

On April 17 another plankton haul was made, this time from the bottom at 330 fathoms. Mud adhering to the weight contained many shells of foraminifera and a few nematode worms. Copepods and a few spindle-shaped diatoms were brought up in the net, as well as several radiolarians.

The next haul was on May 15 through four feet of ice. The net was drawn up from 800 feet and was highly luminescent from the many copepods captured. These continued to emit light for some time after being brought back to the laboratory. The sample also contained several types of diatoms, radiolarians, many small gastropods and some algal fragments.

After the sun disappeared on April 19 the amount of daylight at noon diminished rapidly so that the work was done in the darkness of the winter night and under severe temperature conditions. Getting a hole through the ice became a considerable problem, and handling the net to drain the sample before it became frozen required rapid and sometimes painful work. Every hope was held, however, for the continuation of the collections so that the changes in the plankton could be followed through the period of darkness. After chopping through five feet of ice on May 28 a successful haul was made from 700 feet, with the expected results. There were no diatoms present, but many copepods—a few being about 4 mm. long.

During the height of the Antarctic summer the diatoms reign supreme in the upper regions of the water. In the Bay of Whales a single vertical haul from a depth to which light penetrates will bring up countless numbers of individuals rep-



PHYTOPLANKTON TAKEN FROM THE BAY OF WHALES.

resenting a score of species. These algae reproduce at an amazing rate during the period of constant daylight and serve as food for hosts of animals. As the winter night approaches there is insufficient light for them to carry on their photosynthetic activities and they disappear. But the animal life continues, subsisting upon the remains of the algae, suspended organic material and stored food reserves In the frigid depths of the bay, under a dozen feet of ice, and in the darkness of the winter night there live vast numbers of organisms defying what seems to us the most inhospitable climate in the world. Actually, however, except for the nearly complete absence of light in the upper regions of the water their environment has not changed since summer, when the blazing sun drove millions of tons of ice out of the bay. The water temperature remains very close to the freezing point throughout the year, and with sufficient food materials present animal life is able to continue even without light. The low temperature reduces organic decomposition to a minimum, so food is abundant, yet it is an expensive diet. The supply is limited because no more is being produced The invertebrates are living on others of their kind; the fishes are eating the crustaceans; the seals, as long as they can find a place to breathe, are living on the fish and crustaceans, dependent upon the return of the sun— and the diatoms.

Another haul was started on June 28, but due to the extremely low temperatures the hole was not completed until the 29th. At that time the temperature was – 52° F. with a 15-mile wind. Working by lantern light in the bottom of the hole was awkward and the water rushed up before a suitable opening had been made. When later cleared with a long-handled chisel, it was found impossible to get a net through the underlying mush and crystals. A 15-foot pole did not reach through to clear water. This dense layer of crystals formed under the solid ice effectively stopped further plankton work, and the studies on plankton distribution through the period of darkness had to be abandoned.

After the return of the sun on August 22 plankton work and all other collections near Little America were greatly handicapped because of ice conditions. Although seal holes were easily reached and appeared to offer a likely place for lowering the net, it was soon found that invariably there was a thick layer of ice at depths of from ten to fifteen feet beneath the surface which prevented the further descent of the net. A few copepods were obtained, however, by bailing water through the net from the surface Pieces of meat suspended in the holes attracted numerous amphipods. An unsuccessful attempt to blast a hole through the thick bay ice resulted only in filling the hole with broken ice, mush and crystals. The first successful catch was made through a large crack which appeared in December. Vertical hauls from 300 feet were made every day that the weather permitted Several Euphausia, amphipods and a few small medusae were obtained with a dip net On the whole there was a disappointingly small amount of plankton obtained because of the difficulty of getting the net into clear water.

With the arrival of the *Bear of Oakland* in the Bay of Whales on January 19, 1935, every opportunity was once more afforded to obtain plankton. A laboratory was set up on board with full facilities for collecting and photographing Vertical and horizontal hauls brought in a rich collection, chiefly diatoms Many of these were in the process of division When a scrim net one meter in diameter and four meters long was towed for one-half hour at the rate of about one knot, an astounding mass of phytoplankton was obtained, completely filling a gallon jar with the thick "planktonic soup." The collecting of plankton was continued for several days at the opening to the Bay of Whales, in the Ross Sea within a radius of 20 miles from the bay, westward along the Ross Barrier to Discovery Inlet, and then northward out of the Ross Sea to New Zealand

South Pacific, March to April, 1935.

MAKING MICRO-MOVIES OF LIVING PLANKTON.
DR. E. B. PERKINS IS SHOWN IN HIS LABORATORY AT LITTLE AMERICA.

Continuous plankton collections were made from Dunedin to Panama, via Easter Island and the Galapagos Islands, by filtering a stream of sea water led off from the main circulating pump in the engine room. The ship's sea water intake is about 15 feet below the surface and the outlet to the plankton net about 10 feet from the ship's side. The arrangement was a good one—delicate organisms were not crushed and there was no rust nor scale to interfere with the routine examinations. The plankton bucket was emptied on the average of three times daily, some hauls being taken during daylight hours and some during darkness in order to bring out diurnal variations. A great variety and abundance of plankton was obtained which, as a complete series of stations at short intervals across the South Pacific, should be of considerable interest.

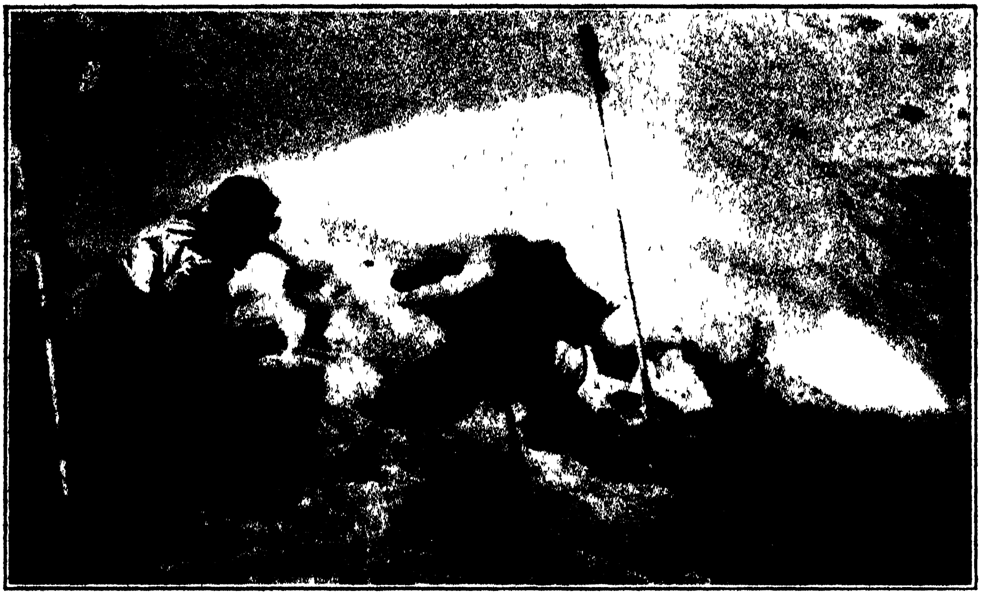
Beginning on the evening of March 24 at Lat. 42° 40′ S. Long 141° 06′ W. and lasting for four days to Lat. 39° 05′ S. Long. 129° 45′ W. there was a spectacular display of the colonial ascidian Pyrosoma. As far as the eye could reach the sea was swarming with these highly luminescent organisms. Some of them were of huge size, being approximately 18 inches long and 5 inches wide.

The plankton collected on this second crossing of the Pacific was perhaps the most interesting of all because of the great variety of forms and the change in general character of the catch during the long, slow voyage. Copepods, of course, were the most numerous, but the variety of form and delicacy of coloring made them of never-failing interest and good photographic subjects Salps, small polychaetes, pteropods, decapods and other small macrurans in abundance, radiolarians, peridinians and a host of other organisms made the thrice-daily collection an event in the day's routine.

Dredging—Bay of Whales

While the *Bear* was waiting for the ice to go out of the bay so that supplies

COLLECTING AMPHIPODS.



SEAL HOLE USED FOR PLANKTON COLLECTIONS, BAY OF WHALES, ANTARCTICA.

could be loaded for the return voyage, there were several opportunities for dredging. The first haul was made on January 22, the dredge being shot in 540 meters of water between East and West Capes. The dredge brought up one complete crinoid and several stalks, four holothurians and several species of polychaetes—some with complete mud cases. Much blue and yellow clay and many stones were brought up in the dredge. Bottom deposit samples were kept. Another dredging from 480 meters off West Cape, where the bottom is rocky and slopes upward to the ridge which parallels the Ross Barrier, brought up tunicates, lamellibranchs, many small sponges, polychaete and sipunculid worms, colonial bryozoans, asteroids and ophiuroids Off East Cape the list of bottom animals at a depth of 490 meters includes polychaetes, tunicates, holothurians, pycnogonids, a large sponge, bivalve mollusks and brachiopods. Other hauls with the dredge in the vicinity of the bay brought much the same variety of animal life. The bottom life is exceptionally rich and well worth investigating further.

The collections obtained, both plankton and dredge hauls, have had a preliminary examination, and the most characteristic or unusual forms have been photographed. Critical examinations have, of necessity, been deferred until a later time, when descriptions of the collections will be made available.

THE PROGRESS OF SCIENCE

THE CHRISTMAS MEETING OF THE AMERICAN ASSOCIATION

ATLANTIC CITY is to be host to the American Association for the Advancement of Science and Associated Societies for the ninety-ninth meeting, which will be held in the week from December 28 to January 2, 1937. Only one meeting has been held in Atlantic City previously, and that occasion was voted most successful The large, well-planned and recently renovated Municipal Auditorium affords admirable meeting places for most events; sections and societies which desire separate rooms have found their needs well met in nearby hotels. Headquarters, auditoriums and banquet halls for all organizations are within easy reach of each other and members will enjoy unusual opportunities for conferences and personal contacts without the expenditure of time often involved in such undertakings at usual meeting places.

Those who have been privileged to attend meetings of the British Association have been deeply impressed by the opportunities offered for social contacts and have felt the value of the associated informal exchange of views between students in different fields The suggestion has often been made that the American Association could perform a real service by introducing similar features to lighten the pressure of overcrowded programs and intense concentration on individual lines of work. The long distances between hotels and meeting places of different groups in our large cities necessarily limit narrowly such contacts and reduce social influences to lowest terms. Atlantic City is well adapted to permit the enjoyment for the once of a new type of meeting, and the executive committee of the association has planned some unusual features to provide for such an opportunity.

The accessibility of Atlantic City to all parts of the country and the large number of affiliated societies which have arranged to meet there as well as the programs already announced indicate that the meeting will be well attended. Two unusual features call for particular mention in this connection. A special program has been planned for Friday, including a general luncheon for members of all sections and societies at which a distinguished representative of the British Association will address the gathering. Final details for this event will be announced later. On Friday evening there will be a special showing of new films on scientific research.

The association has accepted an invitation from the old and justly famous scientific societies of Philadelphia to adjourn to that city for Saturday. Programs for different groups are being arranged The American Philosophical Society, the Franklin Institute and the Philadelphia Academy of Natural Sciences are cooperating in the arrangements. A complimentary luncheon and a visit to scientific institutions of the city complete the day's program.

The evening sessions in Atlantic City will follow the usual plan of the association Monday evening is devoted to the address of the retiring president, Dr. Karl T. Compton, of the Massachusetts Institute of Technology. The Sigma Xi Lecture on Tuesday evening is to be given by Dr. Henry G. Knight, chief of the Bureau of Chemistry and Soils, on the topic, "The Effect of Traces of Selenium in Soils on Plants, Animals and Public Health." The Wednesday evening address, sponsored by the United Chapters of Phi Beta Kappa, will be delivered by President James R. Angell, of Yale, on "The Scholar and the Specialist." On Thursday evening occurs the address of the president of the American

THE MUNICIPAL AUDITORIUM AT ATLANTIC CITY

HEADQUARTERS OF THE AMERICAN ASSOCIATION, WHERE THE PUBLIC LECTURES, MOST OF THE SCIENTIFIC SESSIONS AND THE SCIENCE EXHIBITION WILL BE HELD.

Society of Naturalists, Professor C. E. Allen, of the University of Wisconsin, on "Haploid and Diploid Generations." Afternoon general sessions will include the following: An address by Drs. Zimmerman and Hitchcock, recipients of the Association Prize award at St Louis, on the subject, "Response of Plants to Hormone-like Growth Substances"; and an address by Dr C C. Little, of the Jackson Memorial Laboratory, on "The Social Significance of Cancer " The long series of vice-presidential addresses is distributed over the days from Monday to Friday, their topics, though chosen with regard to the special field of the investigator and his section, appeal also to workers in related fields, often in a wide circle Thursday afternoon is devoted to the Naturalists' Symposium, for which this year the topic chosen is "Supra-specific Variation from the Viewpoints of Biology and Paleontology "

The programs of the sections and societies are replete with interesting material, and it is impossible to do more than refer to a few items in a brief notice such as this Symposia and discussions on problems of to-day are included in almost every program, such as those concerning cellular physiology, genetics and development, speed and the airplane, experimental populations, climatic variations and weather predictions, biological effects of radiation, properties of protoplasmic surfaces, radiant energy in the treatment of disease, the cortex and behavior, insects in relation to man

The Cancer Symposium planned by the Section on Medical Sciences promises to be the most comprehensive presentation on that subject yet worked out and the outstanding event of the meeting. Seven separate sessions extending from Tuesday to Friday inclusive list invited papers on various aspects of the subject which together present a thorough survey of this field. Questions concerning the biological aspects of radiation constitute the first session; the relation of hereditary and constitutional factors to the occurrence of cancer is considered in the second session; two sessions following are devoted to carcinogenic substances, the relationship of sex hormones, the significance of viruses and of inhibitory agents Thursday will be devoted to tissue culture work and the metabolism of cancerous tissue. On Friday afternoon Dr Walter Schiller, of Vienna, will lecture on changes in the conception of carcinoma. The tremendous activity manifested in this field of cancer research recently makes this symposium timely for bringing together views on what is a most important problem in human biology.

Several societies have announced special demonstrations, and the Meteorologists plan to send up some unmanned balloons if the weather permits. Finally the science exhibition, which has for years grown in variety and interest, bids fair to be even better this year. It will command the attention of all in attendance at Atlantic City.

HENRY B. WARD,
Permanent Secretary

THE MEETING OF THE FOUNDER SOCIETIES OF THE AMERICAN INSTITUTE OF PHYSICS

A THREE-DAY meeting of all the Founder Societies of the American Institute of Physics took place on October 29, 30 and 31 at the Hotel Pennsylvania, New York City. This was the largest meeting of physicists ever held in America. The actual registration was over 900, but there were perhaps an additional 300 who did not register. Some of the general sessions were attended by approximately 1,000 people.

The societies meeting together were the American Physical Society, Optical Society of America, Acoustical Society of America, Society of Rheology and the American Association of Physics Teachers. This is the first time that these, the only national physical societies in America, have met simultaneously. They commemorated the fifth anniversary of the American Institute of Physics. Since one of the broad purposes of the institute is to bring about cooperation between pure science and the applications of this science in industries, it was appropriate for this meeting to emphasize industrial physics. Besides the scientific sessions there was a large group of exhibits illustrating applications of physics and instruments used in measuring physical quantities. The most recent text-books in the field of pure and industrial physics were also on display. Much interest was centered around these exhibits, and there were often as many people visiting the exhibits as there were attending the scientific sessions.

One of the features of the meeting was a symposium on the training of physicists for industry In preparation for this symposium, the American Institute of Physics sent out questionnaires to many prominent industrial physicists inquiring as to which elements in their training have proved most valuable. The many painstaking replies to this questionnaire showed an enormous interest in the kind of preparation an industrial physicist should have and provided much material which was reviewed and classified by the principal speakers at the symposium. Dean Homer L. Dodge, of the University of Oklahoma, discussed this material from the point of view of the educator, while Dr. A. R. Olpin, director of research of the Kendall Mills, interpreted the answers from the point of view of the industrialists. Many valuable facts concerning the training of physicists were brought out in these papers. Industrialists felt that in many cases students were studying too much in the field of atomic and nuclear structure at the expense of fundamental and classical physics. It was their recommendation that more attention be paid to the fundamentals and that most of the specializing be taken up after employment in industry. There is in industry a decided need for men trained in the ability to apply mathematics to physical problems. It is often helpful for those going into industry to study, besides their fundamental physics, a few engineering subjects and especially to have facility with ordinary shop practice and to be able to make simple drawings for design work. Almost as important as a person's technical knowledge in industry is his ability to cooperate with other people. The industries have no use for the brilliant but eccentric and self-centered research scientist. Furthermore, since a man must be able to transmit his ideas to others, the need for better training in the writing and speaking of good English was stressed

A series of invited papers constituted a symposium on the applications of physics in industry. The need for physicists on the staffs of industrial companies was brought out very clearly by Dr. Zay Jeffries and Dr. E Q. Adams in their paper on the metal industries, by Dr. E. C. Sullivan in his paper on the glass industry and by Dr. Paul D. Foote in his paper on the oil industry. These men pointed out how great is the need for physical research if other industries wish to follow the great progress which the electrical industry has made in the last fifty years. Dr. Joseph Slepian discussed some of the problems arising in the electrical industry. Some of the phases of physics which can be applied more generally were discussed by Professor J. P. Den Hartog of Harvard in his paper on vibration. He pointed out how important the question of resonance in mechanical systems is and how often such resonance leads to a breakdown at some unexpected time. Dr. Clark Millikan brought out the fact that whenever the margin of safety has to be drawn very narrow, such as in the airplane industry, where excess weight must be kept to a minimum, the application of physics is especially important. One can not guess at results in this field. He must know exactly how stresses are distributed and where unnecessary parts may be reduced in order to keep the weight down and yet not reduce the safety factor. Dr. Millikan emphasized that more and more in the future a thorough training in the fundamentals of physics will be necessary for an engineer. The vice-president of Bemis Industries, Inc., Mr. John Ely Burchard, discussed the need for greater applications of physics in the building industry. Mr Burchard felt that here was a wonderful opportunity for the applications of the principles of physics to increase the comfort of the ordinary man. As an example of how physics may contribute to the convenience of mankind in general, Dr. O. E Buckley, of the Bell Telephone Laboratories, traced in detail the solution of a problem in communication At every stage in this problem progress was made by the application of physical principles

Taken as a whole this symposium constituted a very convincing demonstration of the necessity and magnitude of physics in the development of industries. The meeting was attended by a number of non-technical executives whose responsibility it is to control the emphasis placed on research in their corporations.

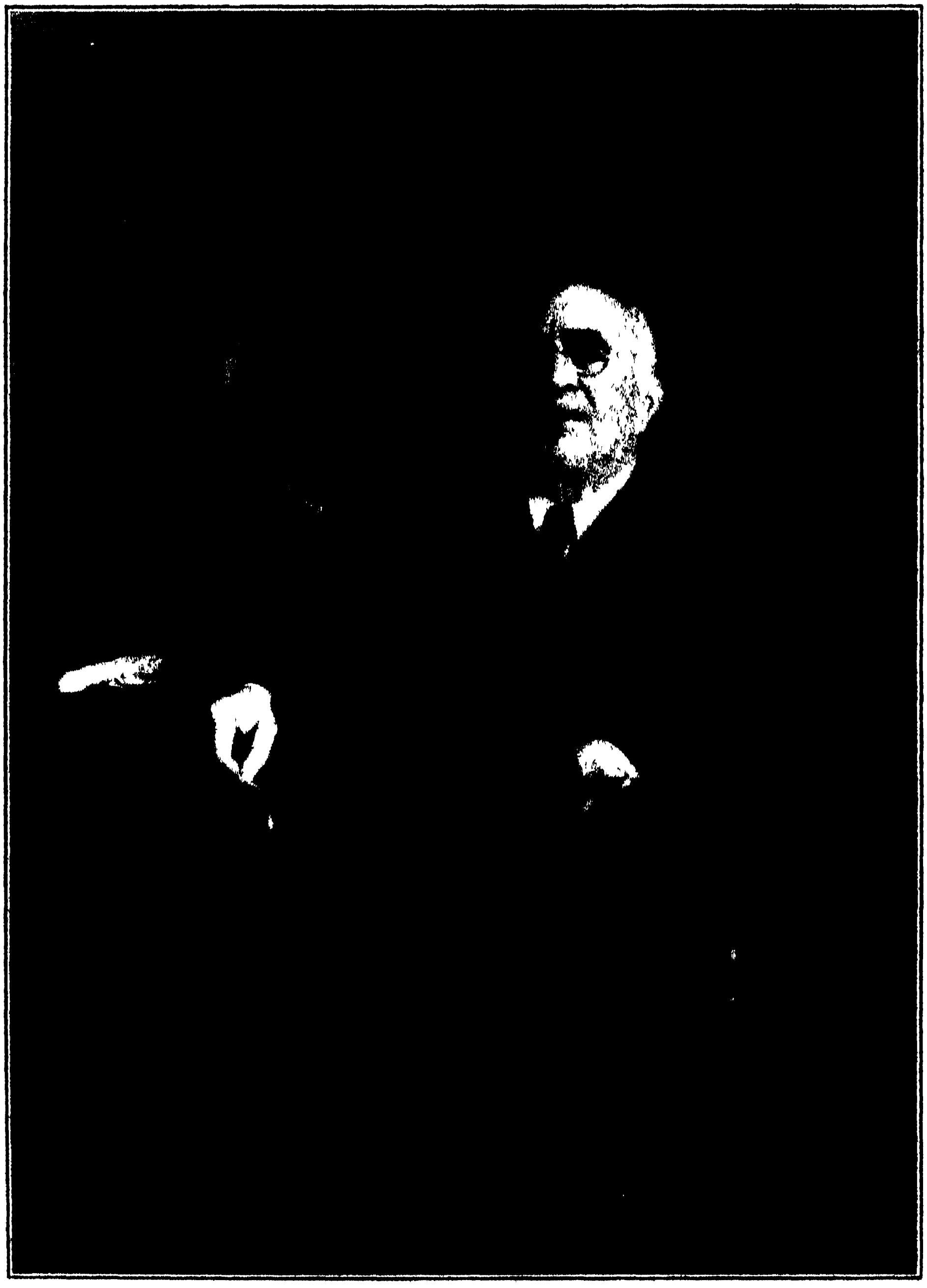
In line with the purpose of the symposium, the institute announced a new *Journal of Applied Physics.* This journal will replace the old journal, *Physics*, and will carry on the program initiated by its predecessor in the publication of research papers. In addition, new features will be developed which will in many ways alter entirely the character of the journal. Papers describing in a broad way the application of physics in particular industries or in the borderline sciences will be published. Laboratories will be discussed with emphasis on the personnel and organization rather than on the buildings and equipment. Biographical sketches of those who are applying physics will be included. Especially for those in the applied physics field, reviews of recent important articles in other journals will be published along with short sketches concerning the authors of these papers. Great interest was expressed in this new journal and the many advance subscriptions placed constitute an endorsement of its purpose of stimulating the industrial application of physics and serving those engaged in making such applications.

Besides the general symposia on industrial physics, there was also a symposium on the applications of optics in modern science, which was arranged by the Optical Society of America, and a symposium on the nature of the solid state, arranged by the Metropolitan Section of the American Physical Society. The search for new sources of light and the applications of optics in the textile industry and medicine were considered in the former. The latter, on the solid state, brought out the fact that modern atomic structure is being closely related to the ordinary bulk properties of materials.

The intense interest of physicists for research in pure physics was indicated by the fact that there were nearly a hundred contributed short papers. Each of these papers described an advance in some particular phase of physics. Each one when considered by itself perhaps does not represent a very great increase in our knowledge, but when one considers the enormous increase indicated by the total number of papers one can well understand why the period of the last few years has been referred to as the "renaissance of physics."

HENRY A. BARTON,
Director

AMERICAN INSTITUTE OF PHYSICS



PROFESSOR RAYMOND DODGE

An oil portrait by Lloyd Bowers Embry recently hung in the Institute of Human Relations.

RETIREMENT OF PROFESSOR RAYMOND DODGE

An oil portrait of Professor Raymond Dodge, presented to Yale University by friends and colleagues of Dr. Dodge, was recently hung in the Institute of Human Relations. Dr. Dodge, who became emeritus last June, was appointed professor of psychology at Yale in 1924, and together with Professors Clark Wissler and Robert M Yerkes, also appointed the same year, shared in the organization of the Yale Institute of Psychology under the chairmanship of Professor Roswell P Angier This institute was a very active research center during the next five years, within which period Dr Dodge, with the collaboration of his graduate students and assistants, published some twenty scientific papers contributing importantly to such topics as optic nystagmus, inhibition, modification of reflex response, protopraxic and epicritic stratification and conditions of human variability.

In 1929 the Institute of Psychology was merged in the reorganization that resulted in the Yale Institute of Human Relations. In these plans and deliberations Dr. Dodge participated with enthusiasm, spending a large part of one academic year working on laboratory construction plans and in traveling in the United States and Europe on scientific missions The new institute, when it became a reality, already owed much to Dr. Dodge; and from its opening day he has played a leading rôle in its many-sided activities The complexities of administrative and committee duties necessarily limited his personal experimental studies in the ideally arranged laboratories of his own design, but through his unfailing counsel and stimulation of younger men within the institute he has multiplied his scientific influence and productiveness during these past few years.

Professor Dodge was the discoverer of fundamental laws in the field of visual perception. In one of his early papers he classified, for the first time, the several types of eye-movements by which visual experience is mediated under varying relationships of the organism and its environment. One line of research flowing from his work has been the eye-movement studies of reading which have developed principles of wide applicability in the teaching of reading in our schools. Another line has led to the development of methods applicable to eye-reflex recording with animals, a field which has been fruitful in studies of learning and conditioning. A third sub-group of his vision studies, that of optic nystagmus, has given results immediately useful in theoretical and clinical neurology The basic character and wide usefulness of Dodge's results and methods could be illustrated by many examples, and it is earnestly to be hoped that his health will permit him to continue scientific publication from his new residence at Tryon, North Carolina

The portrait, a reproduction of which accompanies this note, is life-size and shows Dr Dodge in his laboratory. He is seated by a small table, on which there are several photographic records, and is holding a magnifying lens in his right hand In the background at the left with its heavy wooded frame depicted in dark red appears a timing instrument. This is a faithful representation of Dodge's historic, and still used, pendulum photo-chronograph, a halftone illustration of which appears at the head of his article, "The Act of Vision," in *Harper's* for May, 1902 In the portrait Professor Dodge is represented as listening with critical attention to some bit of psychological theory that an associate is trying out on him The artist, Mr. Lloyd Bowers Embry, a recent graduate from the Yale School of Fine Arts, has given us a remarkably successful picture of Raymond Dodge the scientist. The expression is both genial and critical, conveying warm friendliness and at the same time giving something of the stimulating challenge so characteristic of the subject of this portrait.

Walter R. Miles

THE TELEVISION DEMONSTRATION

THE latest television demonstration conducted for representatives of the press by the Radio Corporation of America and the National Broadcasting Company jointly on November 6 focussed attention anew on the field tests in this new art which are proceeding in the New York area. To guests gathered in the RCA Building at Radio City, a forty-minute program illustrating RCA experimental developments was brought by radio.

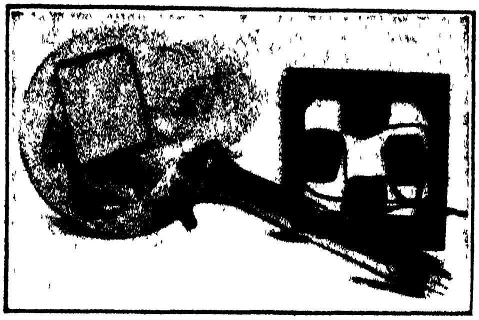
David Sarnoff, president of the Radio Corporation of America, reported on results of the field tests conducted by the company engineers since they were inaugurated on June 29 of this year. Lenox R. Lohr, president of NBC, told of the practical problems presented in staging performances of the air.

Although demonstrations of laboratory television had previously been given, this was the first to be conducted under practical working conditions. It represented the first showing of a complete program built for entertainment value as well as a demonstration transmission. It also included the first showing of a new 12-inch receiving tube, which reproduces a picture on a 7½ by 12-inch screen—the largest screen yet employed.

The program originated in NBC studios in the RCA Building, which are linked by both ultra-high frequency radio and coaxial cable with the transmitter atop the Empire State Building In this instance reception of the signals from the Empire State transmitter was accomplished in a room on the sixty-second floor of the RCA Building.

DR. V. K. ZWORYKIN

HOLDING THE "KINESCOPE," OR CATHODE RAY RECEIVING TUBE.

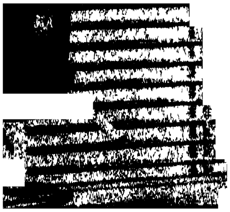


THE "ICONOSCOPE"

THE DEFLECTION OF THE ELECTRON BEAM FOR SCANNING THE MOSAIC IS ACCOMPLISHED BY A MAGNETIC FIELD THE DEFLECTION COILS ARE ARRANGED IN A YOKE WHICH SLIPS OVER THE NECK OF THE "ICONOSCOPE" THE ASSEMBLED DEFLECTING UNIT IS SHOWN AT THE RIGHT OF THIS PHOTOGRAPH BESIDE THE TUBE

Mr. Sarnoff said that the distance over which the experimental programs had been received exceeded immediate expectations. He reported that in one instance the combination of a location favorable to reception and the extreme height of the transmitter had enabled consistent operation of a receiver forty-five miles from the Empire State Building. Speaking of interferences encountered in the tests, Mr. Sarnoff said that they had been found to be mostly man-made, and therefore susceptible of elimination. He also stated that RCA was planning to rearrange its television transmitting and reception equipment to advance from a basis of 343-line scanning to the higher definition of 441 lines.

The demonstration recalled to many present how rapidly progress had been made in the new art, since all previously developed methods of mechanical scanning were discarded and work begun on the creation of a completely electronic system. The "Iconoscope," or eye of this system, which was developed by Dr. V. K. Zworykin in the RCA laboratories, has been brought to a high state of development. This is the device in which light from the image to be transmitted falls upon a plate covered with hundreds of thousands of tiny, mutually insulated photoelectric particles, each one of which forms one electrode of a condenser which is capable of collecting an electrostatic charge independently of its neighbors. When traversed by an electron beam to accomplish scanning, each condenser gives up its electric charge to produce an electric signal impulse whose intensity varies in proportion to the accumulated charge. That energy is amplified and its product ultimately employed to modulate the television transmitter. The individual photo-electric particles on the plate of the "Iconoscope" are so small that the scanning beam, whose diameter is only a fraction of a millimeter, is calculated to cover more than a hundred of them at any one instant.



THE TELEVISION CAMERA

THE CONTROL AT THE LEFT REGULATES THE HEIGHT OF THE CAMERA ON ITS DOLLY. THE CONTROL AT THE RIGHT PROVIDES A RAPID VERNIER CONTROL OF FOCUS. THE LOWER, CENTER LEVER IS FOR STEERING TWO VIEW FINDERS ARE PROVIDED FOR THE CONVENIENCE OF THE OPERATOR IN FOLLOWING OBJECTS OR SCENES AT DIFFERENT HEIGHTS.

The heart of a television receiver in the

RCA system is the "Kinescope," or cathode ray tube. This is the tube in which an electron beam moves across a flat surface of luminescent material in its end, lighting it up as it goes in proportion to the light and shadow of the picture being reproduced

Some of the work now being done in the RCA laboratories toward the creation of more efficient equipment for television reception was discussed in a paper presented on October 31 before a joint meeting of the American Physical Society and the Optical Society of America by H W Leverenz, who is associated with Dr. Zworykin in electronic research. Mr Leverenz's paper described efforts to produce more efficient luminescent materials, one result of which would be brighter images on screen of a cathode ray tube in a television receiver.

It was apparent from Mr. Leverenz's paper that radio science, not finding needed materials in existence, has had to engage in chemical research, to build special laboratories and to seek to create new combinations of crystalline structures by rearranging their molecules One fact which this research has already turned up is that absolute purity of materials used in experimentation does not necessarily make for the most efficient results in their use in cathode ray tubes. It is, however, highly important to be able to control very accurately the addition of any foreign or "impure" substances which may make for the production of more light in the tubes. F. M.

THE NON-INHERITANCE OF ALLERGIC DISEASES

The prevailing concept that the allergic diseases are inherited was refuted by Dr Bret Ratner, clinical professor of children's diseases at the New York University College of Medicine, in a paper presented before the Association for the Study of Allergy at its fourteenth annual meeting in Kansas City.

His conclusions, based upon investigations covering a period of fifteen years, indicate that susceptibility to allergic diseases is not transmitted through germplasm, or the genes, which are the carriers of hereditary traits. Allergic diseases, including asthma, hay fever, eczema and urticaria, are acquired by the individual under certain circumstances from the inhalation of pollens, animal or vegetable dusts, or contact with them, or from the ingestion of foods.

In an intensive study of 250 allergic children and 315 normal children and their respective families, Dr. Ratner has shown that the incidence of allergy in the family of the allergic child is approximately the same as that of the normal child.

From 7 per cent. to 10 per cent. of the total general population are afflicted. His observations also show that only rarely is there a so-called allergic family in which a large proportion of the members are allergic. About 50 per cent. of the families, both of allergic and normal children, show no allergy in their lineage. There was found to be an average of 2.5 members per family suffering from allergy. No conformity with the simple Mendelian laws of inheritance in allergic case histories was found.

Approximately half of the children studied showed symptoms of allergy in the first year of life and practically all the children manifested their allergic symptoms before the eighth year. The development of allergy in children is to a large extent due to chance. The production of allergic syndromes depends upon the amount of protein to which the individual is exposed, the state of permeability of the mucous membrane which ordinarily acts as a barrier, the ability of the body to rid itself of invading protein substances and the intervals at which such exposures occur.

This concept is borne out by many

years of experimental work in which Dr. Ratner and his coworkers actually produced asthma in the guinea pig. This was consummated by subjecting the animals to a special environment containing antigenic dusts The animals inhaling such a dust show no symptoms after several hours' exposure. When returned to the same environment two or three weeks later these animals develop dyspnea and show all the symptoms of asthma The reproduction of a disease such as asthma, under experimental conditions, precludes the necessity for regarding it as dependent upon hereditary factors.

Dr. Ratner and his coworkers also demonstrated that a child may become sensitized in the uterus of the mother as a result of undigested food proteins entering her circulation and thence traversing the highly permeable placenta, and thus invading the fetal circulation. Children manifesting allergic symptoms upon first contact with a new food have not necessarily inherited such an intolerance, but have acquired their allergic state congenitally.

The hope held out by these studies is that in so far as susceptibility to allergic diseases is not proven to be inherited through germ plasm, proper preventive measures can be instituted to control and to a large extent eradicate this common ailment which is present in every tenth person M. S.

METHYLENE BLUE AS AN ANTIDOTE FOR CYANIDE AND CARBON MONOXIDE POISONING

In former days potassium cyanide was notorious as a fatal poison It has the property of uniting with the hemoglobin or red coloring matter of the blood and of preventing it from transferring oxygen to the tissues. Since the tissues can not survive without oxygen, asphyxiation and death take place In 1932 it was announced by the writer at the University of California, Berkeley, California, that the aniline dye, methylene blue, should be used as an antidote for cyanide poisoning This was deduced theoretically from a study of evidence gathered from experiments of other scientists, together with those which the writer performed on rats and rabbits.

This dye has been used for purposes of staining in histology for a long time. There are several impure varieties or unsuitable forms such as the double zinc salt which should be avoided. Only U.S.P. medicinal or chemically pure dyes should be used. The solution is most effective when made up fresh before using. Preferably the amount of dry dye to be used should be on hand and the mixing in distilled water should be done just before using, as an aqueous solution oxidizes rapidly. An intravenous injection of 50 cc of a 1 per cent solution is usually successful In some cases a second dose or even more may be administered after a short interval of time

Physicians have been slow to adopt this therapy. A few months after the writer's announcement at a meeting of the Society for Experimental Biology and Medicine in Berkeley that methylene blue should be used in cases of cyanide poisoning, three policemen were brought into the emergency ward of a San Francisco hospital poisoned by liquor. There was a distinct odor of cyanide about them, and the stomach contents showed that cyanide was present. The old methods outlined in the texts failed to produce any revival and the men died. The methylene blue treatment had not yet been recognized by the American Medical Association, and the information was therefore not available to physicians.

A few months after this a despondent student took cyanide and was likewise brought into the emergency ward. Dr. Geiger, the physician in charge, telephoned various people to find out what to do and happened to call one of the men who had heard about this treatment. Nothing was to be lost in administering the methylene blue as the man was almost dead. His respiration had stopped and the heart sounds were barely audible. He was cyanosed and cold. Quickly they mixed up a 1 per cent. solution of methylene blue and injected it intravenously Before the injection was completed the man began breathing, regained consciousness, opened his eyes and talked. In a few hours he was normal and told his story of disappointment. Since this first case a number of others have been revived from death by cyanide poisoning. The latest case was that of a man who drank two ounces of hydrocyanic acid in San Francisco last June He was brought to the operating table one half hour afterwards, rigid and motionless The breathing had stopped and no pulse beat could be detected. After the injection of methylene blue he recovered rapidly. This was the first case in which a man has lived after drinking the poison in the acid form.

Since hydrocyanic acid is used in the mining of gold, in spraying fruit trees and in fumigation of ships, accidents can be minimized by having this antidote ready in case of emergency.

It has also been found by the writer that methylene blue is an antidote to carbon monoxide poisoning and has been used in resuscitating a number of victims. Since the affinity which hemoglobin has for carbon monoxide is about 300 times that for oxygen, the hemoglobin is unable to function in transferring oxygen. Without oxygen, life can not go on; the tissues become asphyxiated and death results. In addition to the fact that the hemoglobin can not function, the respiratory enzyme which is a link in the transfer of oxygen to the tissues is poisoned and the chain of oxidation is stopped at this point also. Methylene blue, which acts as an oxygen carrier by virtue of its ability to become reversibly oxidized and reduced, presumably takes the place of the hemoglobin and the respiratory enzyme until these are able again to perform their normal functions.

The importance of prompt treatment, especially in the case of carbon monoxide poisoning, is seen when one considers the effects of oxygen lack on such sensitive cells as are found in the brain and kidney. Irreversible injury takes place in a very short time. Permanent damage may result in loss of memory or improper elimination by the kidney The injection of methylene blue hastens recovery and eliminates the long delay involved when carbon monoxide poisoning is treated by the inhalator method In the *Journal* of the American Medical Association is the history of several cases treated by methylene blue with controls which happened to be present. In the one instance two victims of carbon monoxide poisoning were brought into the emergency ward; the more severe one was given the methylene blue injection while the other one was not treated by this method. The latter required many hours to recover and was still suffering from the effects while the former had completely recovered. In another instance, five victims were taken to the hospital at Los Angeles. The two most severe cases were given the methylene blue injection and the others were not, with the result that the treated cases recovered, while those not receiving treatment were still suffering from the poison.

In conclusion it may be stated that, in cases of poisoning by either cyanide or carbon monoxide, methylene blue injections have been shown experimentally and clinically to be an effective antidote.

MATILDA MOLDENHAUER BROOKS

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